

New Scientist

WEEKLY January 17-23, 2015

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New type of pain found in the brain

SPOOKY ACTIONS

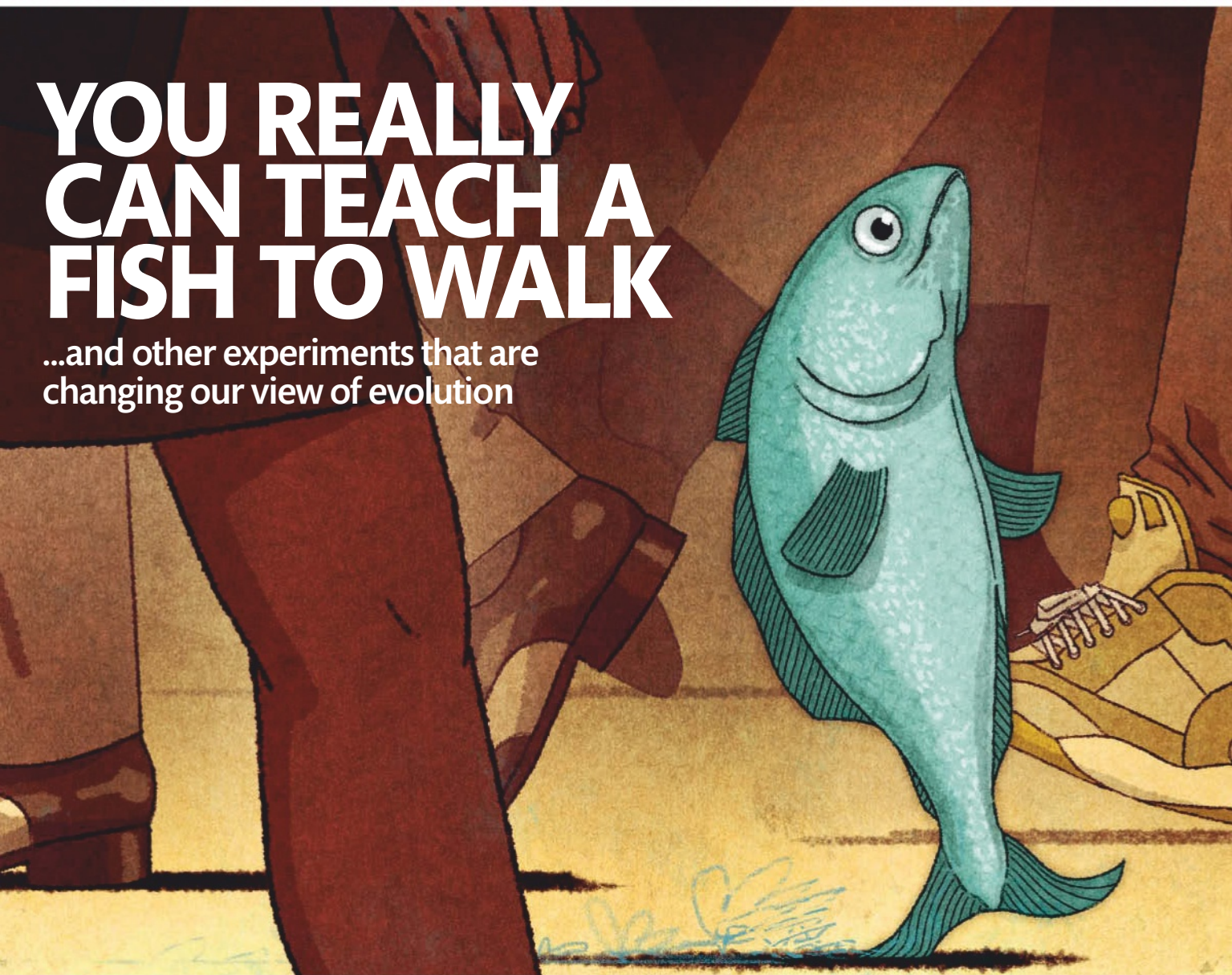
Why humans love a pointless ritual

CLIMATE CRUSADE

Pope set to call for action on warming

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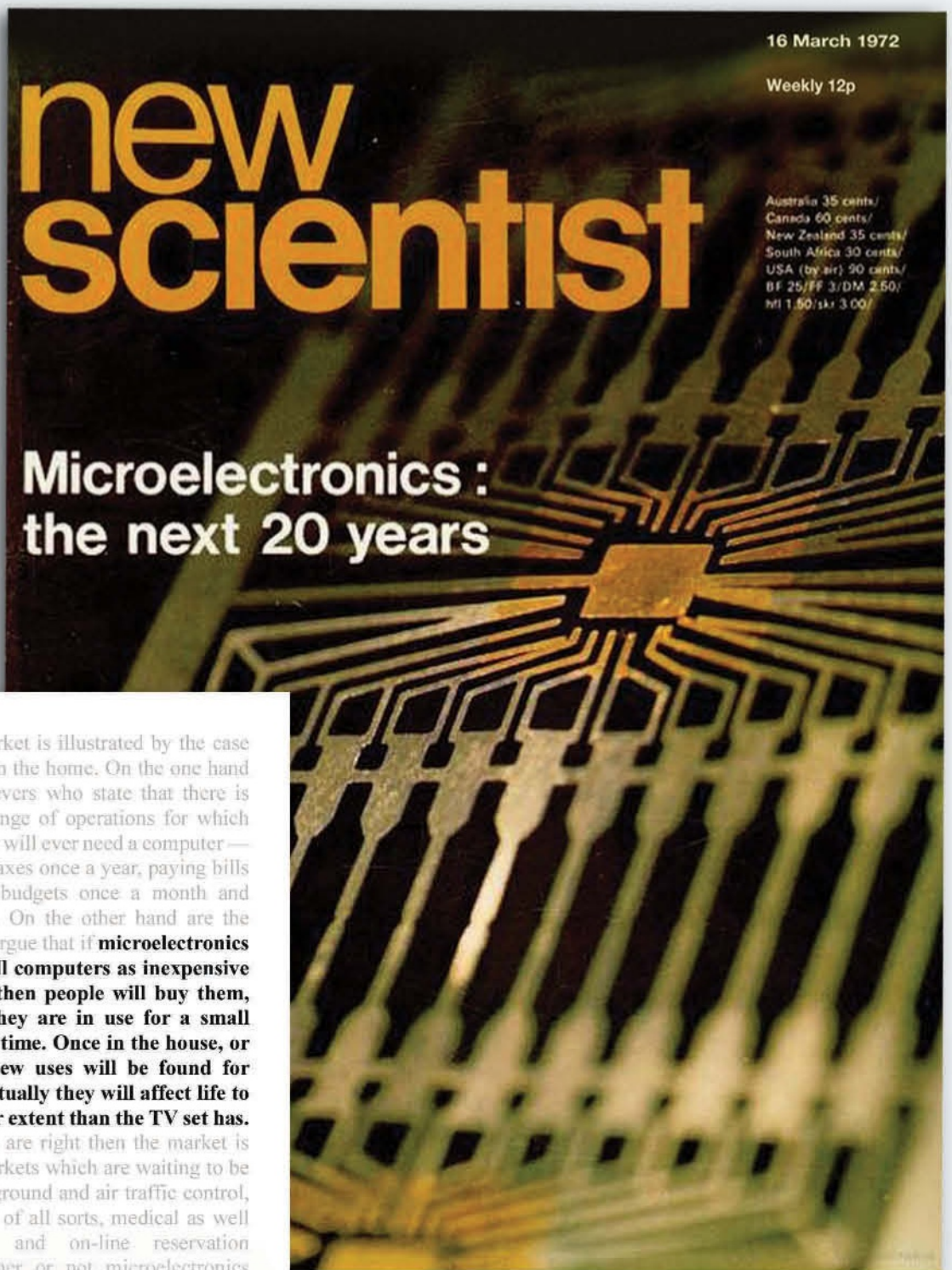
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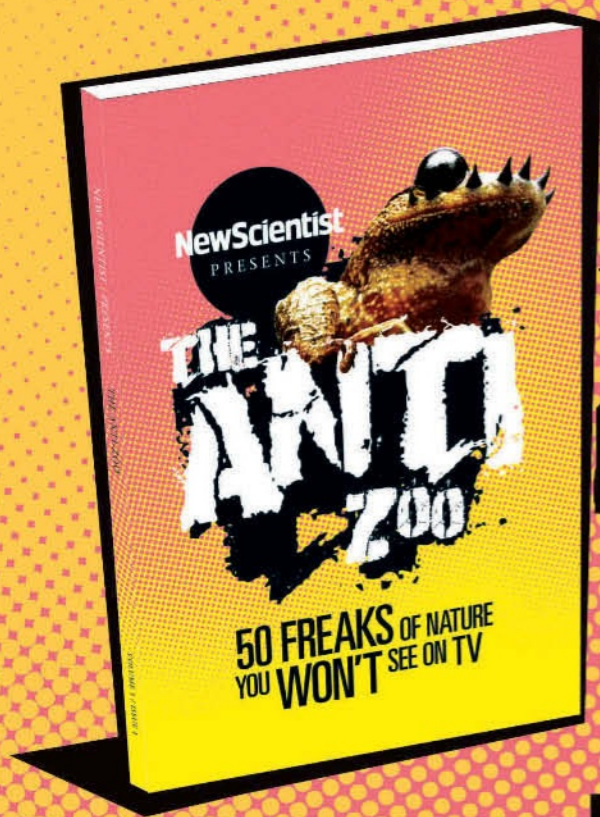
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This elastic market is illustrated by the case for computers in the home. On the one hand are the disbelievers who state that there is only a small range of operations for which the householder will ever need a computer — estimating his taxes once a year, paying bills and balancing budgets once a month and very little else. On the other hand are the optimists who argue that if **microelectronics can make small computers as inexpensive as telephones then people will buy them, even though they are in use for a small fraction of the time. Once in the house, or small office, new uses will be found for them and eventually they will affect life to an even greater extent than the TV set has.** If the optimists are right then the market is huge. Other markets which are waiting to be opened up are ground and air traffic control, process control of all sorts, medical as well as industrial, and on-line reservation systems. Whether or not microelectronics has this particular future depends on improvements in what we already have today — not on new materials, new



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NewScientist

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New galactic life cycle reveals some come back from the dead



NASA/JPL/CALTECH

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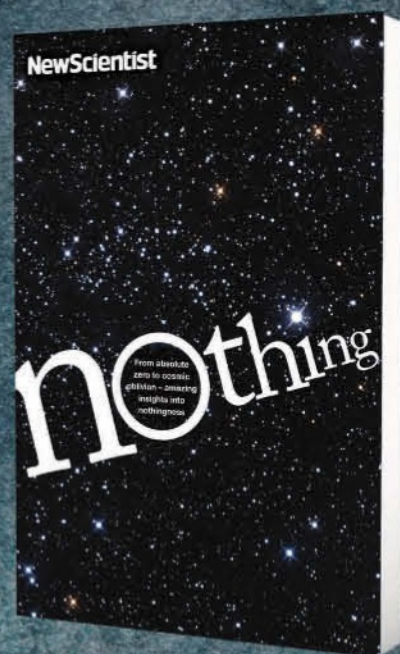
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110 High Holborn,
London, WC1V 6EU
Tel +44 (0) 20 7611 1200
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CONTACTS

Contact us

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Who's who

newscientist.com/people

General & media enquiries

enquiries@newscientist.com

Editorial

Tel 781 734 8770
news@newscientist.com
features@newscientist.com
opinion@newscientist.com

Picture desk

Tel +44 (0) 20 7611 1268

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IMAGE: GALILEO BEFORE THE ROMAN INQUISITION.
1857, BANTI, CRISTIANO (1824-1904) / PRIVATE
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And yet it moves

The pope's stance on climate change is a refreshing departure

WHEN talk turns to the church's relationship with science, it's usually not long before someone invokes Galileo, persecuted as a heretic by the Inquisition despite having evidence to back his view that the Earth moves around the sun. This sorry episode exemplifies the church's attitude to science, people still argue.

So it will surprise many to learn that the Catholic church has not only accepted the evidence for climate change but is preparing to act on it as a matter of social justice. Pope Francis will soon publish an encyclical exhorting Catholics to be "Good Samaritans" on this issue (see page 11), and is even planning a multifaith summit to spread the word.

That is important. For all the railing of secularists against the idea that the church has any special claim over morality, and despite its influence being on the wane (*New Scientist*, 3 May 2014, p 30), many people heed religious authority more readily than any scientific or economic argument. And the pope's case is one that leaders of rich, carbon-intensive nations are reluctant to put forward: that they owe it to the world's poor to cut emissions.

Not every churchgoer will be swayed. Evangelicals are among the staunchest of climate sceptics; even those who accept the reality often view it as God's will. It remains to be seen if the pope can appeal to these recalcitrants – or if

the jeering of denialists will take on a theological, rather than scientific, tone (to which we can only say: god help us).

It was 350 years before a pope admitted that the church had wronged Galileo, whose reputed parting shot was to say of the Earth: "*eppur si muove*" – "and yet it moves". In contrast, it has taken the Vatican hardly any time to accept that Earth is warming. It helps that the Bible contains precious few verses pertinent to carbon emissions. Perhaps we will start to see evidence reshaping the Vatican's views on other issues where scripture still holds sway: the role of contraception in tackling population growth, say. One can only pray it will. ■

Free speech for all

LAST Sunday, UK prime minister David Cameron marched through Paris, arm-in-arm with other world leaders, in a show of support for free speech following the bloody attack on the satirical magazine *Charlie Hebdo*. The next day, Cameron said he wanted to curtail free speech.

He didn't put it exactly like that. In a speech detailing plans for new surveillance powers, he said

he would ban communication methods that cannot be read by the security services (see page 6). "Do we allow safe spaces for [terrorists] to talk to each other? I say no we don't," he declared.

This stance ultimately requires either a blanket ban on encrypted messages, and/or "back doors" built into the platforms used to send them, such as the wildly popular WhatsApp. Neither is

practical; perhaps just as well, because neither is a good idea even in principle. The first would destroy any hope of preserving online privacy, whether for lovers, dissidents or shoppers. The second would be a gift to hackers as well as spooks – whose tactics to date have hardly inspired trust.

In short, outlawing safe spaces for terrorists means outlawing them for the rest of us, too: that is how online freedom works. And restricting freedom of speech is no way to defend it. ■



What about free speech online?

Attack, hack, snoop

"AMERICAN soldiers, we are coming, watch your back!" That message and others like it were apparently tweeted by the US military's Central Command on Monday, after hackers claiming sympathy to Islamic State broke into its Twitter account. On the same day, UK prime minister David Cameron raised the prospect of tighter electronic surveillance.

There has been a spate of hacks in France following last week's terrorist attacks in Paris. One group took over several French municipal websites, adding an Islamic State flag and Arabic music. Meanwhile, hackers affiliated to Anonymous have started a counter-operation called #OpCharlieHebdo. They have taken down at least one French site said to have jihadist links, and posted a list of Twitter handles

that they claim belong to its members.

Meanwhile, Cameron said in response to the Paris attacks that he would pursue tougher surveillance laws in the UK if his party forms the next government. Changes could include resurrecting the draft communications data bill, nicknamed the "snooper's charter". Proposed in 2012 and later shelved, it would give the government access to records of individuals' emails, text messages and internet browsing history.

Cameron also implied he would want to ban communication methods that security services can't currently access, even with a warrant. Many took that to mean instant messaging apps like WhatsApp and iMessage, which are encrypted.

See Leader, page 5

Cancer drug cull

CALL it the bonfire of cancer drugs. From April, new cancer patients in England will no longer be able to receive a number of expensive treatments including three breast cancer medicines.

"The Cancer Drugs Fund has been criticised as a short-term fix for the problem of expensive drugs"

Established in 2011, the Cancer Drugs Fund (CDF) currently spends £280 million a year on cancer treatments that are too expensive, considering their efficacy, to be otherwise approved. Having reviewed the system, NHS England is removing nine drugs from the fund's list because they are deemed to offer too little value for money. The number of conditions that several other drugs can be used for has also been reduced. In total, this means 25 treatment options will no longer be available.

A few new drugs have been added to the list, including panitumumab for bowel cancer.

NHS England has also negotiated price reductions on some drugs. The annual budget for the fund will rise to about £340 million. Without the changes, the fund's spending would have hit £420 million, NHS England says.

The CDF has been criticised as a temporary fix for the problem of expensive drugs, and for being unfair to those with other diseases, who can only get standard NHS-approved drugs without paying extra. From April, only people who have already started on removed treatments will continue to receive them.

TODD KOROL/REUTERS/CORBIS



Tar sand oil: needed in Texas

Indian neutrinos

INDIAN physicists are going underground. Their government has given the green light and \$235 million funding to build the India-based Neutrino Observatory (INO), the country's first underground laboratory to study the weakly interacting, nearly massless subatomic particles.

The experiment will place a 50,000-tonne magnetic detector in a cave 1300 metres beneath Ino Peak in southern India. This will be the world's most massive magnet, outweighing the largest

magnet at the Large Hadron Collider by a factor of four.

The idea is to detect neutrinos produced by interactions between cosmic rays and Earth's atmosphere. Placing INO in a cave protects it from being swamped with noise from other particles, because these can't pass through rock as easily as neutrinos.

INO's position near the equator will also allow it to see neutrinos that originate in the sun and pass through Earth's core. This may help physicists learn why there is more matter than antimatter in the universe.

Oil's pipe dream

WILL it end up being a hollow victory? The Republican-controlled US Congress has passed a bill to approve the Keystone XL pipeline, which will deliver oil from tar sand fields in Canada to Texas – but it may yet be vetoed by President Barack Obama.

Backers of the pipeline say the oil will boost the US economy and increase energy security. But opponents say it will make the US reliant on a dirty source of oil and

delay cuts in greenhouse gases necessary to halt global warming.

While the bill to approve the pipeline was passed by Congress, the margin of victory failed to hit the two-thirds majority needed to overturn Obama's threatened veto. Obama has said he will oppose approval of the pipeline if it adversely affects the climate.

"It's irresponsible to be pushing dirty projects like this," says Susan Casey-Lefkowitz at the Natural Resources Defense Council in Washington DC. "We need to be united across party lines fighting climate change and backing clean energy."

Driven to drink

WORK hard, drink hard. The largest ever analysis of working hours and alcohol consumption has found that people who work over 48 hours a week drink more than people with standard working weeks.

Marianna Virtanen at the Finnish Institute of Occupational Health in Helsinki and her colleagues pulled together data about more than 330,000 people from 14 countries, including the US, UK and Germany.

Their study is the first to calculate how likely hard-workers are to develop potentially dangerous drinking habits. Compared with a standard 35 to 40-hour week, people working between 49 and 54 hours a week were 13 per cent more likely to drink at "risky" levels – defined as 14 drinks a week for women, and 21 drinks a week for men. This was the case regardless of gender, location or socioeconomic group (*The BMJ*, DOI: 10.1136/bmj.g7772).

The study provides strong backing for the European Union Working Time Directive, which gives those in EU countries the right to work no more than a 48-hour week. But many still end up putting in over 50 hours to earn faster promotions or strive for a living wage through overtime.

Beware AI dangers

IS THE future safe from a robot dystopia? Stephen Hawking and Microsoft research director Eric Horvitz aren't convinced. They have signed an open letter offering cautious advice for the field of artificial intelligence, which was published this week by the Future of Life Institute, a research organisation in Boston.

The letter highlights the potential for AI to do good, but argues that several steps must be taken to ensure that future machines are beneficial and reliable. For instance, researchers

need to show that their creations work as intended and are safe from cyberattacks. They should also explore how to maintain "meaningful human control" over intelligent machines, in order to avoid "undesired consequences".

"I think it's very important that everybody knows that AI researchers are seriously thinking about these concerns and ethical issues," says Francesca Rossi, a computer scientist at Harvard University, and one of the first to sign the letter. "We have to make sure that machines will behave in a way that we think is right."

SpaceX doesn't mark the spot

"CLOSE, but no cigar this time," tweeted SpaceX CEO Elon Musk after his latest rocket launch ended with a bang.

On 10 January the firm successfully sent an uncrewed Dragon capsule on its way to the International Space Station – its fifth such mission. However, plans to land the first stage of the Falcon 9 rocket on a boat ended in failure.

Most rockets are single use, falling into the sea once their fuel is spent, and this increases the cost of space flight. So SpaceX was keen to try and land the first stage of its Falcon 9 rocket, with an eye to reusing it.

In preparation, SpaceX positioned an autonomous barge off the coast of Florida. The landing was to be

Falcon 9's first on a solid surface, after two previous water landings.

On its way down, 10 minutes after take-off, the rocket successfully hit the barge, but came in too fast and was destroyed shortly after. Musk said it was too dark and foggy to get a video of the landing, but SpaceX plans to analyse data from the flight and try again in the future. The Dragon capsule safely docked with the ISS on Monday.

A successful landing will place SpaceX in a league of its own, as reusable rockets could slash the cost of getting to orbit. Competitors are already starting to take notice – last week the French space agency, CNES, announced plans to develop its own reusable rockets.



What goes up...

60 SECONDS

Long-lost Beagle

Has Beagle 2 been found? The UK's Mars lander, launched in 2003, crash-landed on the Red Planet and was never heard from again. As *New Scientist* went to press, the UK Space Agency had announced plans for an update, and rumours are rife that a NASA satellite has finally spotted the spacecraft.

23andPfizer

Where there's spit, there's money. 23andMe, the California-based company that analyses a customer's DNA from spit samples, is to share genetic, lifestyle and symptom data from 650,000 consenting individuals with the pharmaceutical giant, Pfizer. Pfizer hopes to uncover links between genes and disease to identify new drug targets.

Why the stripes?

Why do zebras have stripes, and how come they vary? A study of 29 environmental variables has found that the number and thickness of black stripes are best explained by temperature, rather than the presence of predators or biting flies, as had been suggested. The stripy pattern may provide cooling and parasite protection in hotter areas (*Royal Society Open Science*, DOI: 10.1098/rsos.140452).

Comet pit stop

Comet Lovejoy will be at its most visible this week. In the northern hemisphere it may be seen with the naked eye as a greenish spot to the right of Orion's belt. Catch it while you can – it won't return to the solar system for 8000 years.

Real-life Nessie

Move over Nessie. A fossil of a prehistoric marine reptile that lived 170 million years ago has been found on the Isle of Skye. *Dearcmhara shawcrossi* was a 4.3-metre-long ichthyosaur that would have lived in shallow seas feeding on fish and squid (*Scottish Journal of Geology*, doi.org/x7g).

Galactic zombies roam the cosmos

A new look at the life cycle of galaxies discovers some that simply refuse to stay dead

Lisa Grossman, Seattle

THROUGHOUT cosmic time, galaxies age a little like humans do: they start out small, grow bigger, stronger and more productive, and eventually shrink and run out of energy as they dwindle towards death.

But recent research presented at the American Astronomical Society (AAS) meeting in Seattle last week shows that there is more than one way to kill a galaxy – and they don't always stay dead.

Unlike in humans, cannibalism seems to be the driving force behind galactic life cycles. Gravity pulls smaller galaxies together to form big ones. Then later on large galaxies – including the Milky Way – continue to eat smaller ones that stray into their clutches.

Such mergers influence a galaxy's health and appearance. In their prime of life, galaxies resemble our own Milky Way: grand spirals full of young stars, with more appearing at a healthy rate. But eventually something

shuts them off, and they turn into spherical blobs full of old stars.

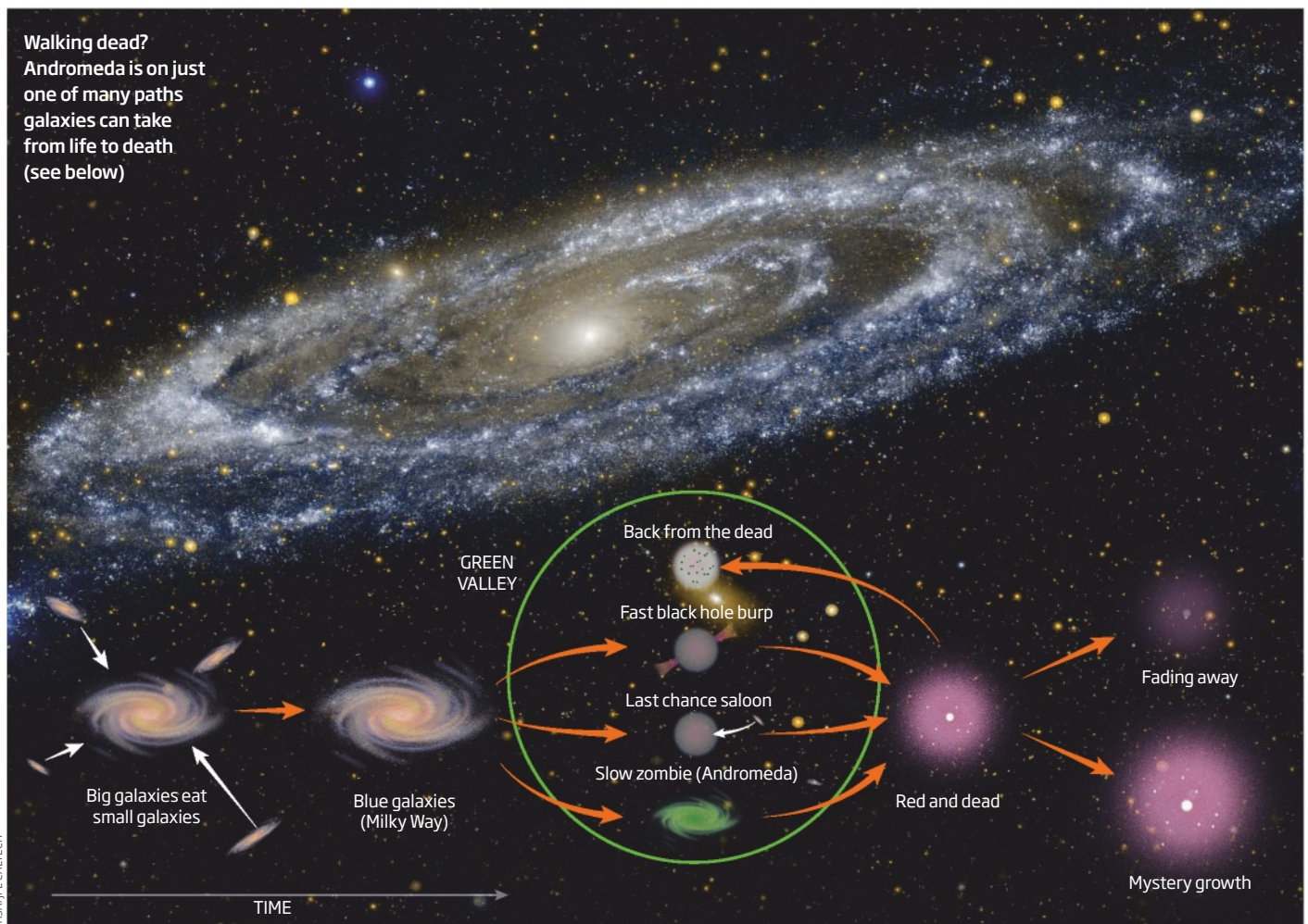
The question is how this happens. Is it quick, like the explorer who turns to dust after drinking from a fake Holy Grail in *Indiana Jones*? Or could it happen so slowly that the galaxy itself may not even realise it is dying?

For a long time the most popular suspect in the ageing process was mergers: two gas-rich spiral galaxies collide and form a new one whose stars are scrambled out of their elegant

structure. Astronomers call the young spiral galaxies “blue”, because young stars tend to be blue in colour, and the old blobby galaxies “red and dead”, because old stars appear red.

That leaves a transition zone between blue and red galaxies called the “green valley”, in part because green light falls

“The galaxies that die quickly probably get a nudge from their central black hole”



In this section

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between blue and red in terms of energy (see diagram, below left), although the stars don't actually look green.

"The green valley is a mess," says Daniel McIntosh of the University of Missouri-Kansas City. "It's like a smorgasbord of all kinds of processes. We have a general picture that galaxies are becoming more red and dead, but how?"

We do know that green galaxies have one thing in common: they are running out of gas. One clue to what might be happening comes from observing the black holes that live at their centres. If a black hole is actively gulping material, it can burp out powerful winds and radio jets that violently expel gas out of a galaxy. Years ago, astronomers noticed that galaxies with active black holes also clustered in the green valley.

"So for a few years, it was sort of, ah, well, this proves everything!" says Kevin Schawinski at ETH Zurich in Switzerland, founder of the citizen science project Galaxy Zoo.

But he realised that a galaxy doesn't have to change from a spiral to a blob in order to change its star formation. Using Galaxy Zoo data, he and his colleagues showed that there are two paths through the green valley: the fast switch-off and the slow fade (*Monthly Notices of the Royal Astronomical Society*, doi.org/x7m).

The galaxies that die quickly probably get a nudge from a central black hole. Schawinski and his colleagues used a radio telescope in the Netherlands to observe four green valley galaxies whose colours indicate that their ages are slightly different, so you can line them up in a time sequence from youngest to oldest.

In their radio images, presented at the AAS meeting, clouds of gas flee the galaxies over about a million years – a pretty short time for a galaxy. One of them also had echoes of jets from the central black hole that aligned perfectly with the ejected gas clouds.

From brimming with life... to red and dead but what happens in between?

TOP: STOCKTREK IMAGES, INC./ALAMY; BOTTOM: NASA

"The black hole is not doing anything any more, it's quiet now, but this is past action by the jets," Schawinski says. While that doesn't prove that the black hole kicked out the gas, it is suggestive.

The slow route across the green valley is more subtle. Sometimes a galaxy can just run out of gas, or enter a mode where its gas is too hot to collapse into new stars. They keep their youthful spiral shapes, but their star formation fades over many billions of years.

"We call these zombie galaxies," Schawinski says. "They're already dead, but they don't know it yet, so they keep going." The Milky Way may even be such a galaxy, although it's hard to tell from inside it. And according to Schawinski, our nearest neighbour galaxy, Andromeda, is probably a zombie.

Last gasp

Some galaxies refuse to conform to either path. In 2011, Katherine Alatalo of the California Institute of Technology and her colleagues found a galaxy called NGC 1266 that looked old in terms of its shape and its colour, but also had a lot of hydrogen and molecular oxygen, which are usually signs

of star formation. It also showed signs of gas flowing out from the central black hole.

"It looks nothing like anything we've seen out of our galaxy," Alatalo says. "It was transitioning in a way that was not obvious – yet it was old."

Alatalo thinks NGC 1266 was caught mid-death throes. It was already in the last chance saloon when a collision with a smaller galaxy finished the job. The shock of the merger moved the gas into the middle, where the central black hole beat it up, Alatalo says, spewing out gas faster than gravity could form it into stars, (arxiv.org/abs/1410.4556).

At the AAS, Alatalo presented a whole cadre of other galaxies in similar straits, culled from other sky surveys (*The Astrophysical Journal Letters*, doi.org/x7n). "We think we caught them on the cusp of transitioning," she says. "They're like people in movies who have been riddled with bullet holes, who give you that one last glance of surprise before they fall to the ground."

But even red and dead need not be the end for a galaxy. Eating a small, gas-rich galaxy delivers a boost of young stars and can also trigger a brief flurry of new star

formation, bringing the host galaxy back from the dead.

"The red and dead galaxy can temporarily cross over into the green valley and then back out again," says McIntosh.

Also at the AAS, Sirio Belli of Caltech presented evidence that galaxies can keep growing even after they stop making new stars. He noted that the dead galaxies we see in the local universe are larger in size than in the distant, earlier universe. That means one of two things, he says: either the nearby dead galaxies died recently, and so had more time to grow before switching off, or they kept growing even after their star-forming days were over, possibly by merging with smaller galaxies.

To tease these two possibilities apart, Belli worked out the ages of distant dead galaxies with the help of a newly installed spectrograph on the Keck telescope in Hawaii that let him peer further back in cosmic time, and measured their physical size using images from the Hubble Space Telescope.

"Zombie galaxies are already dead but they don't know it yet, so they keep going"

He found that the younger galaxies are bigger, so they did have more time to grow before dying. But that only accounts for about half of the post-mortem increases he observed. He also found that much of the growth in the early universe happened too quickly to be explained by mergers. The true nature of these galaxies remains a mystery.

For our own galaxy, the future is somewhat clearer. Whether we are a walking zombie or not, the Milky Way is on course to collide with the Andromeda galaxy in about 4 billion years. Watching the wreckage of other galaxies in the universe will help us figure out what our own destiny will be. ■

Pain really can be all in your mind

Jessica Hamzelou

YOU'RE not imagining the pain. But your brain might be behind it, nonetheless. For the first time, it is possible to distinguish between brain activity associated with pain from a physical cause, such as an injury, and that associated with pain linked to your state of mind.

A fifth of the world's population is thought to experience some kind of chronic pain – that which has lasted longer than three months. If the pain has no clear cause, people can find themselves fobbed off by doctors who they feel don't believe them, or given ineffective or addictive painkillers.

But a study led by Tor Wager at the University of Colorado, Boulder, now reveals that there are two patterns of brain activity related to pain. One day, brain scans could be used to work out

your relative components of each, helping to guide treatment.

"Pain has always been a bit of a puzzle," says Ben Seymour, a neuroscientist at the University of Cambridge. Hearing or vision, for example, can be traced from sensory organs to distinct brain regions, but pain is more complex, and incorporates thoughts and emotions. For example, studies have linked depression and anxiety to the development of pain conditions, and volunteers put in bad moods have a lower tolerance for pain.

So does this mean we can think our way into or out of pain? To find out, Wager and his colleagues used fMRI to look at the brain activity of 33 healthy adults while they were feeling pain. First, the team watched the changing activity as they applied increasing heat to the volunteers' arms. As the heat became painful, a range

of brain structures lit up. The pattern was common to all the volunteers, so Wager's team called it the neurologic pain signature.

The group then examined whether the volunteers could control the pain by thought alone. "We asked them to rethink their pain, either as a blistering heat, or as a warm blanket on a cool day," Wager says. Although the volunteers couldn't change the level of activity in the neurologic

"This can help us see the physical basis of the emotional and cognitive contributions to pain"

pain signature, they could alter the amount of pain they felt. As they did this, a distinct set of brain structures linking the nucleus accumbens and ventromedial prefrontal cortex became active (*PLoS Biology*, doi.org/x55).

"It's a major finding," says Vania Apkarian at Northwestern University in Chicago. "For the first time, we've established the possibility of modulating pain through two different pathways."

The upshot is that brain scans

comparing the strength of activation in the two brain networks could help work out how much of someone's pain has a physical cause, and how much is down to their thoughts and emotions. This could benefit those with conditions such as fibromyalgia, which is poorly understood and characterised by pain all over the body.

About a quarter of those with chronic pain who contact UK charity Action on Pain say that their doctors don't believe them. "The problem is that chronic pain is invisible," says chairman Ian Semmons.

"Doctors may tell people with chronic pain that they're hysterical, or think that they are making it up," Wager says. "But [the new work] can help us to put a physical basis on the emotional and cognitive contributions."

The findings build on recent work by Apkarian's team, who discovered that chronic back pain seems to be associated with a pattern of brain activity not usually seen with physical pain. In fact, the brain regions active in Apkarian's volunteers were the same as those active in the volunteers controlling pain with their thoughts in Wager's study.

This suggests that in chronic pain conditions, psychological pain may overtake physical pain as the main contributor to the overall sensation. This may explain why traditional pain relief such as opioids don't offer much reprieve.

Wager's study suggests that cognitive therapies and techniques such as neurofeedback – where people learn to control their brain activity by watching how it changes in real time – might offer a better approach.

"In the next five to 10 years, we'll see a huge change in the way clinicians deal with pain," says Seymour. "Rather than being based on what the patient says, we'll be building a richer picture of the connections in that person's brain to identify what type of pain they have." ■



Emotions affect the pain you feel

INSIGHT Vatican's climate appeal

Can the pope win hearts and minds on climate?

COULD one man succeed in spurring decisive action on global warming? Pope Francis, leader of the world's 1.2 billion Catholics, plans to release a ground-breaking appeal to combat climate change, in a major document called an encyclical. Its message will be spread to congregations around the world by Catholic clergy, mobilising grassroots pressure for action ahead of the key UN climate summit in December in Paris.

The encyclical may be published as early as March, and may be couched in terms of the biblical parable of the Good Samaritan, which teaches that we have responsibilities to our fellow humans. It will be the first encyclical to address concerns about a global environmental issue, and will provide "important orientation" to all Catholics to support action on climate change, says Bishop Marcelo Sánchez Sorondo, chancellor of the Pontifical Academy of Sciences and Social Sciences in Vatican City. Last May, he organised a workshop there discussing the science and impact of climate change. Participants issued a hard-hitting statement, which laid the groundwork and set the tone for the encyclical.

The most likely thrust of the pope's appeal will be that failure to combat climate change will

condemn the world's poorest people to disproportionate harm. "The sad part is that the poorest three billion will be the worst affected by the impacts of climate change, such as sea level rise and drought, but have had least to do with causing it," says Veerabhadran Ramanathan, a climatologist at the Scripps Institution of Oceanography in San Diego, California, and a scientific adviser to the Vatican on the encyclical. "The world's richest billion people, by

contrast, are responsible for 50 to 70 per cent of the greenhouse gases that are to blame." This, he hopes, will be the evidence on which the pope rests his moral case for action to remedy what, in the pope's view, is a global injustice.

Scientists and religious figures who champion urgent action hope that by focusing on moral rather than scientific or economic grounds, the pope can help persuade climate sceptics by appealing to their consciences. "Science has taken this issue as far as it can, and now it's in the domain of policy-makers to bring about action which requires changes

in behaviour," says Ramanathan. "As a scientist, I have no authority to demand changes in behaviour, but religious leaders do."

The pope's call may also help persuade some of the most trenchant opponents of action on climate change: evangelical Christians in the US. A survey of 3022 Americans, published in November by the Public Religion Research Institute in Washington DC, found that only 27 per cent of white evangelical protestants polled believe in human-generated climate change.

"A papal encyclical may shock millions of evangelicals into reality," says Richard Cizik, president of the New Evangelical Partnership for the Common Good in Fredericksburg, Virginia. "It could be a real game-changer, because many evangelicals are still consumed by right-wing political ideology and apocalyptic theology." It could also resonate in the US Congress, nearly a third of which is Catholic – split about equally between Democrats and Republicans.

But not everyone is convinced the move will have a major impact. "It's unlikely that any one action, even by someone as influential as the pope, will suddenly alter the global political landscape," says Naomi Oreskes, a historian of science at Harvard University. "But many of us are hopeful that papal authority will help some people revisit and reconsider the issue." Andy Coghlan ■



A moral stance could just be a hit

Super-fast penis evolution seen in lizards

THEY say size matters, but what of speed? In some lizards, penises have been evolving incredibly quickly – up to six times faster than other traits.

Fertilising eggs when they are still inside your mate is a tricky business. To rise to the task, male genitals can come in different shapes and sizes, even among closely related species

of animals. This suggests penises evolve particularly quickly – something that has now been shown in Caribbean lizards for the first time.

Julia Klaczko of Harvard University and colleagues looked at 25 species of *Anolis* lizard and compared penis shape with two other, non-sexual traits: leg length and the size of the flap of skin on their necks.

Hemipenes – as the genitals are known – come in a wide variety of shapes, but Klaczko's team focused on their length, width and lobe size. They looked at how quickly these features

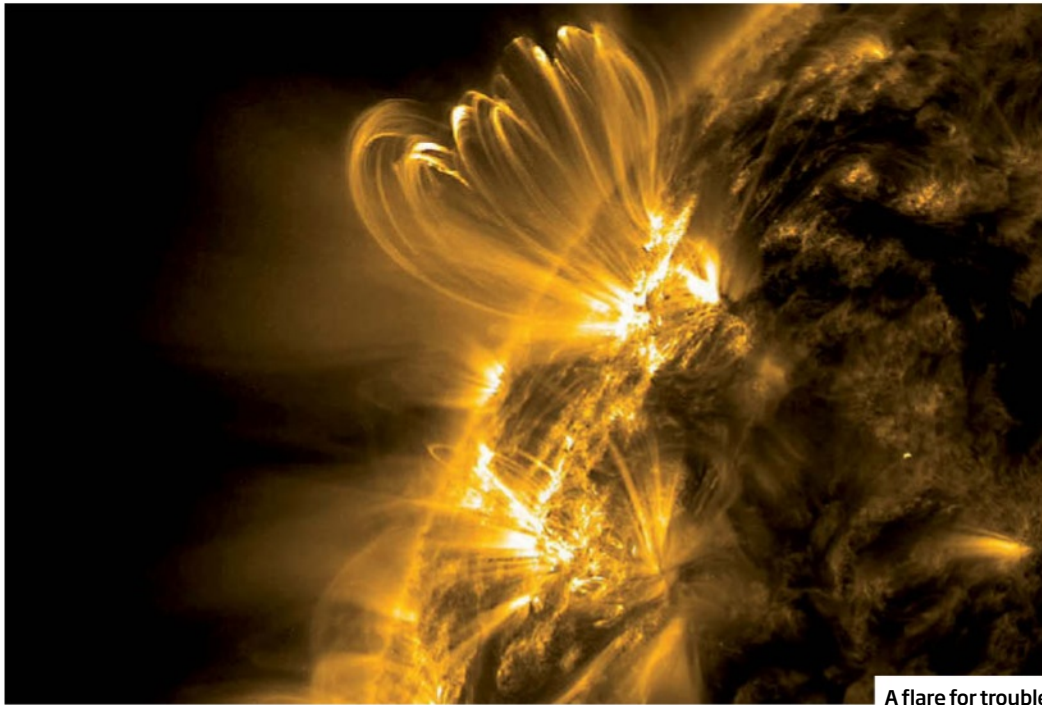
changed on the *Anolis* family tree. The results surprised them. *Anolis* hemipenes have been evolving six times faster than the other traits (*Journal of Zoology*, doi.org/x7d). "That the differences were that high was a great finding," says Klaczko.

The finding is extraordinary, agrees Kirsten Nicholson of Central Michigan University in Mount Pleasant. "The

"The idea that genitals evolve rapidly has been around for a long time. Now we have support"

idea that genitals evolve more rapidly has been around for a long time. Now we have support."

This fast evolution could be explained by female preferences for new male shapes that better fit or stimulate them, or by a gendered arms race. Wherever they have been examined, the female *Anolis* genitals match the shape of the corresponding penises, says Gunther Köhler of the Senckenberg Research Institute and Natural History Museum in Frankfurt. So it's likely that female genitals are evolving just as fast. Penny Sarchet ■



A flare for trouble

And now, the space weather

Hal Hodson

WE ALL rely on weather forecasts to plan ahead and ensure our day won't be ruined by an incoming storm. You can even get a minute-by-minute forecast of where you are with a glance at your phone. Not so lucky are those in charge of critical satellite infrastructure that risks being wiped out by a solar storm.

A new forecasting system launched this week aims to change that. Dubbed FLARECAST, it uses the latest in solar physics and high-performance computing to create space weather forecasts as accurate as those for Earth.

Astrophysicists at the US National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center, and the UK Met Office's Space Weather Operations Centre

manually forecast the sun's behaviour just once a day. They scan live streams of data for potentially dangerous bursts of plasma called coronal mass ejections (CMEs).

"Space weather forecasting is probably where terrestrial weather forecasting was 30 years ago," says Catherine Burnett, the Met Office's space weather programme manager. "If we've got a CME en route, we can only give people a window that's plus or minus 6 hours. That's not good enough for them to do proper planning."

FLARECAST will autonomously churn out updated forecasts every minute, and aims to predict when the sun will erupt, not just alert Earth when it already has. The network was switched on at the start of the year and officially launched at a conference in Brussels, Belgium, on 15 January.

"In Boulder [at NOAA] they have extremely experienced people, but it's not automated. Someone is sitting there looking at the data," says Manolis Georgoulis of the Academy of Athens, Greece, who is leading the project. "We're trying to rely on fully automated methods."

The system's primary source of data is NASA's Solar Dynamics Observatory, which supplies measurements of magnetic fields on the solar surface as it orbits the sun. Physicists can work back from this data to model the fields in the corona above the surface of the sun. These are too weak to

"FLARECAST aims to predict when the sun will erupt, not just alert Earth when it already has"

measure directly but are responsible for CMEs, since the coronal fields twist as the surface roils and eventually snap. The energy released can hurl charged particles away from the sun and towards Earth where they damage satellites, knocking out GPS and communications.

While an outage may not have a direct impact on the average person's day, it can be fatal in other arenas. "If you're driving your car and your satnav isn't working for 10 minutes, no big deal," Bill Murtagh of NOAA told policymakers at the Dupont Summit in Washington DC in December. "But if you're landing a plane with quarter-mile visibility and a crosswind in Juneau, Alaska, and you're relying on GPS that's gone for a couple of minutes, you've got a big problem."

The scale and depth of society's dependence on GPS is growing, says Burnett. Oil companies need precision GPS to dock tankers safely in port, large-scale farmers program their tractors with planting or ploughing routes guided by GPS, and financial services use the satellite network to ensure precise timing when executing high-frequency trades.

An extreme example of this dependency comes from Alaska. The state's snow ploughs clear mountain roads in zero visibility, tracing a virtual path with only GPS as their guide. A solar storm and GPS outage could be fatal.

Future humans will have even greater need of accurate, timely space weather forecasts, says Peter Gallagher, a member of the FLARECAST team at Trinity College Dublin, Ireland. Earth's magnetic field protects us from high-speed electrons and protons. In space or on Mars – which has no substantial magnetic field – such solar weather can kill. If we ever want to expand into the solar system, we will need to have a better idea of when deadly weather might hit.

"If you're going to be working on the surface, exploring or tending crops, you're going to have pockets of magnetic field [for shelter] and you need to know what the space weather forecast for today is going to be," says Gallagher. "We'd like to provide that forecast." ■

Romans defied the rules to house wives in forts

TALK about hiding in plain sight. Women are thought to have had no official role in Roman army activities. But now a monument that's been sitting in the centre of Rome for almost 2000 years is adding to the evidence that soldiers ignored a ban on marriage, and that the wives or daughters of commanders might have taken part in triumphal ceremonies.

Archaeologist Elizabeth Greene told the 8-11 January annual meeting of the Archaeological Institute of America in New Orleans about six females depicted on the iconic Trajan's column in Rome, Italy, a triumphal monument to a military victory.

The figures on the column are attendants holding sacrificial offerings at a military religious ceremony, a role usually carried out by boys. But six of them are clearly recognisable as women or girls, says Greene, of the University of Western Ontario in London, Canada. She thinks the six females may have been wives or daughters of senior officers.

Scholars have studied the column since the 18th century, so how has no one noticed these women before? For starters, it's more than 30 metres tall, so much of it is hard to examine close up. Plus, you see what you look for, says Lindsay Allason-Jones of the University of Newcastle, UK: "Trajan's column tends to be studied by military historians, looking for details of how things were built and machinery."

Only men could join the Roman army, and during his reign from 27 BC to AD 14, the emperor Augustus forbade rank and file soldiers from marrying, a ban that lasted nearly two centuries. Classical texts on the Roman army have little to say about women. So, for many years, most archaeologists believed no women were attached to the army, says Allason-Jones.

This started to change in the late 1980s, when Allason-Jones started finding evidence that the wives and children of centurions – officers who commanded units of 80 soldiers –

lived with them at border and provincial forts.

And in the early 1990s, Allason-Jones and Carol van Driel-Murray of the University of Leiden in the Netherlands found shoes in women's and children's sizes at Vindolanda, the site of a Roman fort along Hadrian's wall in northern England. They also found bronze plaques called diplomas, which were given to provincial soldiers who earned Roman

"Trajan's column has been studied for centuries, so how has no one noticed women on it before?"

citizenship by 25 years of service, that mention their wives and children.

Now, Greene has reassessed that evidence. She says about 40 per cent of the thousands of shoes found at the site clearly belonged to women or children rather than men. And of some 1000 diplomas catalogued, 43 per cent mention a wife, children or both. At Vindolanda, Greene says, the non-legal, de facto wife of a foot soldier probably lived outside the fort with their children, and had to work because the average soldier wasn't paid enough to support a family. Van Driel-Murray thinks some women may have worked within the fort as cooks, seamstresses or washerwomen.

Penelope Allison of the University of Leicester, UK, says that shoes and brooches from a site in Germany from the same period indicate that women there may have lived inside forts. "They just lived in the barracks with everybody else," she says, "engaging with the military community."

But it might be some time until everyone believes this happened. "I'm still trying to convince the older generation, mostly classical scholars and historians, who have problems with these forts being mixed communities," says van Driel-Murray. Whether the women Greene found on Trajan's column will tip the scales remains to be seen. Jeff Hecht ■



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Chimp brains miss out on the groovy feature built into ours

COULD a lopsided gap help set us apart from our primate cousins? Our brains and chimps' are built differently in the areas that give us our language and social skills.

The human brain has a 4.5-centimetre-long groove running deeper along the right side than the left. Chimp brains lack this asymmetry, as François Leroy of the French National Institute of Health and Medical Research in Saclay, and colleagues, have discovered. The groove's function is unknown, but its location suggests it played a role in the evolution of our communication abilities. "One day this will help us understand what makes us tick," says

Colin Renfrew of the University of Cambridge, who was not involved in the study.

Although our brain is about three times the size of a chimp's, anatomical features that only the human brain possesses are surprisingly hard to find. One known difference is in a region called Broca's area, which is also involved in speech and is larger in humans than chimps.

The asymmetrical groove in humans was also known, but the new study, in which 177 people and 73 chimps had brain scans, revealed it is almost completely lacking in the other primates (*PNAS*, DOI: 10.1073/pnas.1412389112). "Asymmetrical brain landmarks may be key features to understand what is so specific in our species," says Leroy, since left and right sides of the human brain tend to perform different tasks.

Did Mercury survive a planetary pile-up?

THE inner solar system may once have been a crowded place – and Mercury its lone survivor. It seems most planetary systems start with many close-in, rocky planets, which later destroy each other.

Our home is unusual compared with other planetary systems; none we have spotted has four inner rocky planets and four outer gas giants. What's more, NASA's Kepler space telescope has

revealed some systems cram several planets closer to their host star than Mercury is to the sun. And Mercury itself is an oddball, with an unusually large iron core.

Kathryn Volk at the University of British Columbia, Canada, has created a computer simulation that explains both oddities at once. She found that nearly all stars form a cadre of rocky planets close to them, and most collide

and destroy each other within a billion years.

Some planets collided almost immediately, while others remained stable for 100 million years, she told the American Astronomical Society meeting in Seattle last week.

The most violent collisions simply vaporise the planets, and because lighter material is blown away by the stellar wind, any surviving planets would be unusually dense – like Mercury.

Is Antarctic ice disc an impact crater?

IT'S round and could have been made by something from space. A scar in the ice shelf 2 kilometres in diameter may be the site of a suspected Antarctic meteorite impact.

In September 2004, Australian scientists noticed a trail of dust 30 kilometres above Antarctica. Remote sensors picked up a big bang on the same day that was later mapped to the area using global low-frequency sound readings. Researchers suspected a large meteorite, but the precise spot remained a mystery.

Last month, Christian Müller, with marine research consultants Fielax in Bremerhaven, Germany, spotted the ice circle during a routine flight. The team collected data to map the circle's contours in depth, but detailed analysis of that data and further studies, including drilling, are needed to determine if a meteorite was the cause, they say.

Two-faced aphids exploit ant masters

IT IS no docile farm animal.

A type of aphid has been found that exploits its ant protectors.

Like other aphids, the round-bodied, sap-sucking *Paracletus cimiciformis* produces honeydew for the ants that farm it. But this species also has a flat-bodied form which the ants take into their nest, where it feeds on their young (*PNAS*, DOI: 10.1073/pnas.1414061112).

David Martinez-Torres of the University of Valencia in Spain and his team discovered that the flat aphids chemically mimic ant larvae, tricking adults into taking them home. "According to our observations, ants that adopt flat aphids do not 'realise' they are being parasitised by the aphids," says Martinez-Torres.

Uber-tidy bees save the day

FOR some, cleanliness is next to godliness. For honeybees, it's a way of saving the hive from disaster. The varroa mite sucks the blood of worker bees' pupae, reducing their immunity to disease, transmitting viruses and sometimes causing the entire hive to collapse.

Bees have one trick up their sleeve: being tidy. Hygienic worker bees find and dispose of infected pupae. To study this behaviour, Francis Ratnieks of the University of Sussex in Brighton, UK, and colleagues placed a section of honeycomb that had been frozen to kill the pupae inside 42 honeybee colonies.

Within a day, most had removed around half of the dead pupae, but some had managed to remove more than 95 per cent (*Journal of Apicultural Research*, doi.org/x68). These super-hygienic colonies also had less than half the varroa mite levels of the less hygienic colonies, and were also less likely to show shrivelled wings – a sign of a virus infection.

"This finding could be very useful for beekeepers as it would reduce the harmful effects of varroa in a natural way," says Ratnieks. "You can breed for this behaviour by screening colonies and breeding the most hygienic." His team confirmed this in a separate study (*Journal of Apicultural Research*, doi.org/x69).



Scans reveal what many women ejaculate at orgasm

WHAT do you think of when you hear the words "female ejaculation"? It was banned last year from being shown in British porn films, but what exactly is it?

The first ultrasound scans on women who express a large amount of liquid from their urethra at orgasm have helped to define the phenomenon. Some women express a small amount of milky fluid – some scientists consider this the female ejaculate. Other women report "squirting" a much larger amount of fluid – enough to make it look

as if they have wet the bed.

Small studies suggest the milky fluid comes from Skene's glands – tiny structures that drain into the urethra. To investigate squirting, Samuel Salama at the Parly II private hospital in Le Chesnay, France, and his team recruited seven women who produce large amounts of liquid at orgasm.

Scans taken as the women climaxed showed that this fluid almost certainly came from the bladder. Two women showed no difference between the chemicals in their urine and the fluid squirted:

in other words, the fluid was urine. The other five women had a small amount of prostatic-specific antigen (PSA) in their fluid – an enzyme not detected in an initial urine sample, but which is part of the "true" female ejaculate (*Journal of Sexual Medicine*, doi.org/x4r).

"There are evidently two different fluids, with two different sources," says Barry Komisaruk of Rutgers University in Newark, New Jersey. It seems some women expel just female ejaculate, others urine or urine with some ejaculate mixed in.

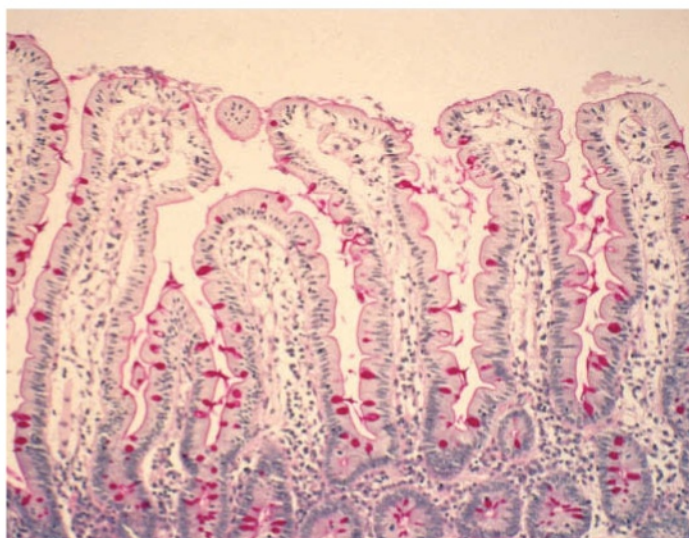
Quick sniff for chemical weapons

PHEW, what an invention! A device that sniffs out tiny quantities of mustard gas and lewisite on the go could help protect workers tasked with cleaning up chemical weapons.

Identifying mystery molecules often requires sophisticated equipment and slow preliminary steps to concentrate samples. Instead, the new approach uses water vapour in the air to process the sample before analysis.

Air containing a potential weapon sample is drawn into the device and zapped with electricity, charging the vapour, which starts to break down chemicals in the sample. A counter stream of air whisks away any highly reactive ions created by the zap that might otherwise destroy small amounts of the broken-down weapon molecules. What's left is then identified by a mass spectrometer.

Yasuo Seto of the National Research Institute of Police Science in Japan, who led the work, says his device can detect concentrations one hundredth of fatal levels and has begun using it to search for weapons abandoned in China after the second world war (*Analytical Chemistry*, doi.org/x6m).



Recipe for growing your own gut

SOON you'll be able to grow your own gut. Take a small sample of human intestine, grind it up and soak it in digestive enzymes, pipette the mixture onto a polymer scaffold and implant it into the abdominal cavity of a mouse. A few weeks later, you will have a tiny segment of fully functioning human gut.

Tracy Grikscheit at the Children's Hospital Los Angeles wants a new way to treat intestinal failure, which is rare but kills almost one-third of babies affected within five years. Replacing the diseased part of the gut with engineered tissue is one

option. Four weeks after the scaffolds seeded with human gut tissue were put into mice, Grikscheit and her colleagues found the transplants had grown and had many of the features typical of the human small intestine. The gut cells could also break down complex sugars into simple glucose (*American Journal of Physiology*, doi.org/x6k).

The work is a crucial step towards treatments in babies, says Grikscheit. "Having a surrogate system in which you can prove the tissue grows properly is important." The next step is to produce larger samples of tissue.

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Stick or twist?

Love at first site

Can a website tell your romantic fortune, and advise whether you should stick with your current partner or move on, asks **Aviva Rutkin**

WHEN Rashied Amini split up with his girlfriend of two years, she said she'd need to see a cost-benefit analysis before she would consider taking him back. At the time, the engineer laughed off the idea. Now, a few months later, he's about to launch Nanaya, an online tool that calculates your odds of being lucky in love.

"I thought, 'I've made cost-benefit models in the past, let me see if I can start doing something like this,'" Amini says. "I was going through a break-up and it was something to turn my attention to."

Amini's former job involved tweaking mission parameters to find the optimal conditions for success in NASA's now-shelved Constellation programme, which

FEELING LUCKY?

Want to run a quick scan on your own love life? Here are a few of the questions Nanaya will ask users when it launches:

- + Do you enjoy talking to strangers?
- + Do you use online dating?
- + Do you want to settle down by a certain age?
- + How many best friends do you have near you?
- + What has been your success in attracting people you're interested in?
- + Would you consider dating someone from your workplace?
- + How lucky are you?
- + How far away would a person have to be that it would impact the quality of a relationship?

looked at building bases on the moon or Mars. With Nanaya, he wants to help people find success in their personal lives. The idea is to forecast your probability of finding a suitable romantic match if you're single, or if not, of finding someone who is a better match.

Amini is far from the first to tot up the pros and cons in search of insight into romance. Before Charles Darwin proposed to Emma Wedgwood in 1838, he wrote his own cost-benefit analysis on the back of an old letter. Marriage would be time-consuming and expensive, Darwin noted, but it did offer constant companionship, "better than a dog anyhow". In the decades since, many

have attempted to distil the messy reality of life and romance into clean formulae, from dating site OkCupid, which mines the data of its millions of users for telltale patterns, to a mathematical model from the University of Washington that can predict whether a couple will get divorced.

For Nanaya to assess your likelihood of finding a good match, you fill out a detailed questionnaire. First, there's a personality test supplied by Traitify in Baltimore, Maryland, which pinpoints different

"Darwin noted that the constant companionship of marriage was 'better than a dog anyhow'"

facets of your personality and the characteristics you'd like in a partner by asking you to pick from a series of images. Another set of questions then identifies how likely you are to meet new people in your daily life. The results are fed into a simulation ➤

◀ that randomly mixes traits across a population of potential matches, so that each member of the population is like a roll of the dice. The size of that population is dependent on how many people you're likely to run into – the more people you might meet, the more rolls of the dice you get.

Dating data

Nanaya spits out scores that measure your selectivity, how much your social network could grow with a given mate, your overall romantic opportunity, and a graph of your prospects over the next few years. Those who are already in a relationship will also be asked a set of questions that scores them on their compatibility and happiness with their partner.

Amini tested Nanaya's algorithm by meeting up at coffee shops with people he had recruited as volunteers for the study through ads on classifieds site Craigslist. He asked them detailed questions about their love lives and ran their data. In some ways, he says, a human life turned out to be more difficult to tackle than a space project.

"I want people to be open-minded when they're going into it, but obviously I also don't want people following it blindly," says

I CAN READ YOU LIKE AN OPEN FACEBOOK

Be careful what you "like" on Facebook. You're opening a small window on your soul.

A machine-learning algorithm can now predict human personality types using nothing but what people like on the social media site. A team at

Stanford University in California and the University of Cambridge used data from a questionnaire filled out by 86,000 people that identified their "big five" personality traits. The results were correlated with their Facebook activity (*PNAS*, DOI:

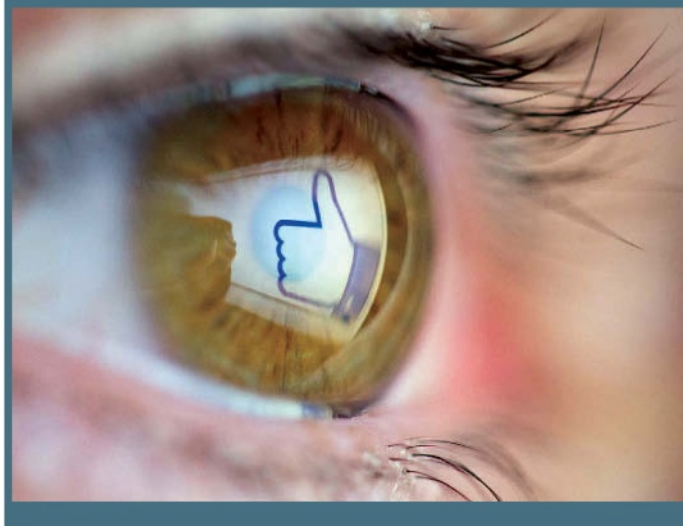
10.1073/pnas.1418680112).

On the basis of between 100 and 150 Facebook likes, the team's algorithm could determine someone's personality more accurately than could their friends and family, and nearly as well as their spouse.

"In the past, my research has looked at how accurately people can judge each other's personalities," says Youyou Wu at Cambridge, one of the study's authors. "It's surprising that computers can do better using just one piece of information – likes."

In 2013, the same group found that Facebook likes can predict private personal information like sexuality.

David Funder of the University of California, Riverside, says predicting a big-five score is impressive, but it is just one component of personality. "This is a very broad way of describing human personality. It's useful, but not intimate," he says. "It doesn't really comprise understanding on any deep level." Hal Hodson



FRISO GENTS/PICTURE-ALLIANCE/DPA/AP IMAGES

Amini. "Nanaya helps you to reflect on what you want in life."

Some psychologists are sceptical about Nanaya's potential. Attraction between people is difficult to predict, says Harry Reis, a psychologist at the University of Rochester in New York. "You simply can't do it from

paper and pencil characteristics."

Paul Eastwick at the University of Texas at Austin agrees that the program is probably incomplete. "Matchmaking algorithms are probably possible in principle, but they would likely need to incorporate data assessed after, not before, two people have

met each other," he says.

An early version of Nanaya will be available at the end of February, and it is likely to evolve as more data comes in from users. Amini hasn't tried the process on himself – yet. "I'll definitely do it," he says, once he finishes developing the prototype. ■

Top poker program is now impossible for humans to beat

WOULD you have bet on it? Poker-playing programs have long been able to hold their own against the best human players. Now there's one that's effectively unbeatable, at least at one of the simpler forms of the game.

Poker is a popular test bed for artificial intelligence research because, unlike in games like chess, each player's assets aren't visible to other players. "The whole interesting part of the game comes from the fact

that you don't have perfect information," says Michael Bowling of the University of Alberta in Edmonton, Canada, who devised the software with his team. The work could have applications in real-life "imperfect information" situations like auctions, where none of the bidders know what others have up their sleeve.

Bowling's team took their previous best program and made a subtle change to the way it learns from experience. The new version is more willing to make plays that had failed in the past but might still work as part of a bigger, more sophisticated strategy. They also fine-tuned it by optimising its use of disc space and memory.

Together, these tweaks made the upgraded program, Cepheus, about a thousand times quicker. That gave the team enough power to compute the perfect strategy for every possible scenario in the two-player poker variant known as heads up limit hold 'em. They have shown that no alternative approach would reliably come out ahead over a lifetime's worth of playing (*Science*, doi.org/x6g).

Cepheus hasn't demystified poker to such an extent that it kills the

"No alternative program could reliably come out ahead at poker over a human lifetime of play"

game. For one thing, the algorithms amount to 12 terabytes of data, so they're not something anyone could learn. Even so, Bowling's team has a public website where anyone can practise against Cepheus or find strategies for specific scenarios.

However, most poker games involve more than two players and often have no betting limits. This makes games harder to analyse, says Bowling.

His techniques could help telecoms firms bid for new radio frequencies. "No one knows the rational way of bidding in a typical spectrum auction," says Tuomas Sandholm at Carnegie Mellon University in Pittsburgh, Pennsylvania. Bob Holmes ■

No time to write? Get letters crafted by bots

HANDWRITTEN notes can be a joy to receive, but a real chore to send. There's the search for a stamp, the trip to the mailbox, and the pain of attempting joined-up writing with fingers more used to texting.

Enter a handful of start-ups that make robots do the chore for you. For a fee, a machine holding an ordinary pen will ink out your message - sent via an app - in a deceptively human hand, even varying the size and shapes of characters for added realism.

"We're not trying to fool people into believing that someone wrote the note for them," says Sonny Caberwal, founder of Bond, a New York City handwriting service that launched in November. "We're trying to give people a tool to express themselves in the way they want."

The handwriting robots are a high-tech update to the autopen machines that recreate multiple signatures on diplomas or politicians' letters. New software lets the robot mimic the different characteristics of a person's handwriting, like the way we join up our letters. Though the bots don't write much faster than an actual person, they can work for long hours without getting tired or making mistakes.

Customers can choose from a number of preset fonts, designed to look messy, stylish, or formal. Or for \$199, Bond will mimic a

customer's own handwriting, and for \$499 they will invite you to work with handwriting experts for a day to improve it first. Bond also offers options based on the handwriting of famous people such as Sigmund Freud.

You can also use the services to send thank-you cards, holiday greetings and birthday cards. The robots could be a handy way for firms to communicate with customers:

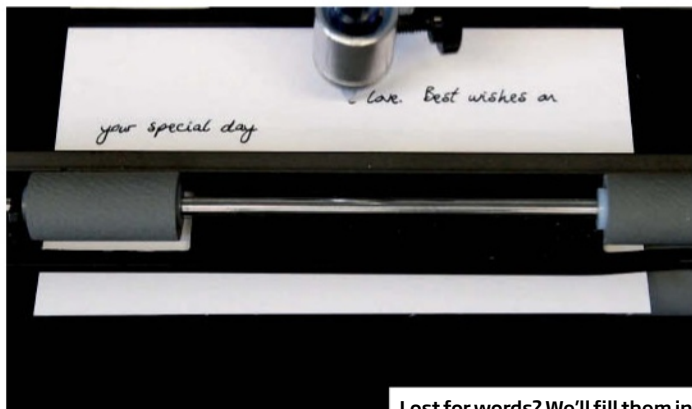
"A robot will mimic the characteristics of a person's handwriting, like the way letters join up"

marketing research suggests that people are more likely to open handwritten letters. MailLift in Austin, Texas, and Handiemail in Chicago already hire humans for this task.

"There's a certain sentimental nature that goes along with receiving an actual note," says David Wachs, who founded the app Handwrytten when he got fed up writing thank-you notes after business meetings.

Etiquette expert Jodi R. R. Smith of US firm Mannersmith says she loves the idea. "Anything that helps people to be more polite and more thoughtful is a wonderful technology."

To watch a Handwrytten robot write a letter go to bit.ly/arobotwrites.
Aviva Rutkin ■



HANDWRITTEN

Lost for words? We'll fill them in

ONE PER CENT



VolcanoBot takes the plunge

Live volcanoes are hardly the easiest or safest places to explore. So NASA is developing robots to do the dangerous work instead. The 30-centimetre-long VolcanoBot1 (pictured) spent four days mapping a fissure of the Kilauea volcano in Hawaii, going 25 metres deep. A lighter, smaller VolcanoBot2 is due to explore Kilauea in March, NASA says. The plan is to send it all the way to the end of the fissure.

"You allowed yourselves to kill innocent people, we will therefore avenge their deaths"

A video purportedly from the Belgian branch of the hacker group Anonymous, aimed at Islamic State and Al Qaeda, was posted on YouTube in the wake of the attack on French magazine *Charlie Hebdo* last week

Cyberattacks get real

For only the second time ever, a cyberattack has resulted in damage to physical infrastructure. A report released by the German Office for Information Security at the end of December describes how hackers infiltrated the network of a steel mill to cause "massive", though unspecified, damage. By sending emails with malicious attachments to employees, the hackers were able to gain control of a blast furnace and cause parts of the plant to fail. The attack is reminiscent of the Stuxnet virus that wreaked havoc on Iranian nuclear plants seven years ago.

Chat to your pet with kittycam

Are you away from home and missing your kitty? A solution was debuted at this year's Consumer Electronics Show in Las Vegas: a wireless camera that lets you watch your pet's every move. Set up the PetCube on your home Wi-Fi and it'll stream a live video feed to a smartphone app. The app lets you and your pet "talk" via a built-in microphone and even play with a laser pointer. Owners can take snaps of their pets and post them on social networks from the app.

NASA





Back to a drowned town

THIS photo first made me think of the desolation of Hiroshima after the atomic bomb. Then, seeing the woman walking through the ruins of her former home town, it made me think of Cormac McCarthy's novel *The Road*, set in a post-apocalyptic North America.

What disaster has befallen this place? It is Villa Epecuén, once a thriving and popular tourist town in Buenos Aires Province, Argentina. People would visit from Buenos Aires to bathe in the apparently therapeutic waters of Lago Epecuén, the salt lake the town was based on. Then changing weather patterns caused the lake to swell.

On November 10, 1985, a dam protecting the town burst and a gradual, seeping flood began. By 1986 the streets were 1 metre under water. By 1991, it was 10 metres.

Finally, in 2009, the waters began to recede. Only one man - 85-year-old Pablo Novak - returned to live there. The image below contrasts the town now with its 1970s heyday, showing the changes wrought by the flood. Rowan Hooper



Photographer

Natacha Pisarenko AP Photo;
inset: Juan Mabromata/AFP/Getty Images

Over a barrel

Plummeting oil prices have been hailed as good news for consumers. But where do they leave the environment, wonders **Fred Pearce**

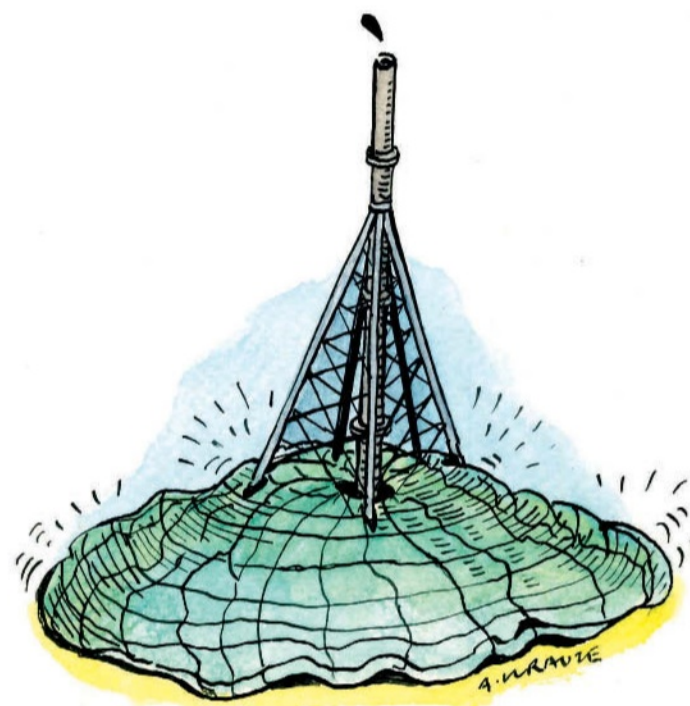
IS THE recent oil price crash good or bad for the environment? For years, environmentalists have been seeking carbon taxes and other measures to ratchet up oil prices to encourage us on to a clean-energy path. But some are now hailing the recent price crash as good for the environment, because it could fatally weaken big oil and its hold on the world's energy system. You could be forgiven for being confused.

What gives? Oil prices have more than halved since last June, to just under \$50 for a barrel of Brent crude, the industry's global benchmark. This is likely to increase the amount of oil burned as fuel, both because people are less careful with stuff that is cheap and because low fuel prices will stimulate economic activity. The price crash will also discourage investment in alternative sources of energy such as renewables. The oil glut shows no signs of easing, as major producers such as Saudi Arabia and other OPEC nations are reluctant to pump less.

"High-priced oil dampens petroleum demand and makes oil alternatives more viable [whereas] lower oil prices reboot oil demand, leading to higher overall production and consumption," according to Deborah Gordon, an energy and climate analyst for Washington DC-based think tank the Carnegie Endowment for International Peace.

In the past decade of high oil prices, people in the US have been driving less, and more economically. Now, the argument goes, gas-guzzlers will be back.

But there are those who think



that the price slump could bring green gains. That's because low oil prices are bad news for big oil and its need to sniff out new sources of the black stuff. In particular, low prices make huge investments in new oil reserves look like bad deals – especially since almost all new reserves have high extraction costs, whether in the Arctic, deep off-shore or tied up in Canadian tar sands. The cheap stuff is running out.

Carbon Tracker, a UK-based think tank on finance, energy and climate, is hailing the environmental benefits of low prices. James Leaton, its research director, says large oil companies have committed \$1.1 trillion over

the next decade in projects that have a break-even price of at least \$95 a barrel. These investments are in trouble if low prices persist – which is possible. While circumstances were different in the 1980s, when oil prices crashed spectacularly, it took well over a decade for them to fully recover. Even shale reserves could be at risk. The giant Bakken shale-oil reserve in North Dakota has a break-even price of almost \$80 a barrel. The industry as a whole could be weakened

"Today almost all new oil reserves are high-cost, whether in the Arctic, deep off-shore or in tar sands"

and supply could shrink.

Observers say a sustained oil price below \$50 a barrel would mean a big hit on investment spending by those companies involved in oil exploration and production. This is already in evidence: ExxonMobil, Royal Dutch Shell and Total have all announced cuts. Jobs are going and investment is being trimmed. Associated industries involved in pipeline manufacturing or those that service the oil industry are also shrinking.

Of course, other things being equal, such an outcome could eventually rebalance the supply and demand equation and push prices back up. But other things may not be equal any more. Some analysts say the oil industry may be approaching a tipping point that means a strong bounce back is less likely than in the past.

What has happened in the coal industry offers clues. Boom is turning to bust there, as a decade-long surge in demand peters out, primarily because of cooling Chinese demand. China has recently set tight limits to future coal burning by 2020. This is already pushing down global coal prices, causing mining companies to mothball expensive new projects. The industry has a term to describe mines that have cost billions of dollars to develop but are effectively worthless: "stranded assets".

New research suggests that around 30 per cent of current oil reserves may end up as stranded assets if the world gets serious about efforts to stem the potential for dangerous climate change

(*Nature*, vol 517, p 187). Study authors Christophe McGlade and Paul Ekins at University College London calculated how much fossil carbon needs to stay underground for a reasonable chance of avoiding dangerous climate change. In the absence of commercially viable carbon capture and storage (CCS), all oil burning will have to cease in 25 years, they say.

McGlade and Ekins are also pessimistic about the industry's hopes for a CCS solution that would allow it to keep burning fossil fuels, saying it looks likely to be too little, too late.

Events later this year may amplify the price signal and its impact on new reserves, if the UN agrees a tough global climate deal to restrict carbon emissions. Making substantial proportions of coal and oil reserves "unburnable" in order to limit global temperature rise to 2 °C could condemn both industries to terminal decline as markets shrink, prices plunge and assets that are expensive to find and develop are left in the ground.

Add in UN climate chief negotiator Christiana Figueres's view that oil price volatility should push the world towards less economically volatile sources of energy – like solar – and you start to see why some observers are describing 2015 as a perfect storm for oil.

So which is best for the environment? Is it better to push up prices to choke off demand, or to push down prices to choke off supply? It is far from clear. But maybe oil and coal are destined to get caught in a double bind, in which both high and low prices create more problems than opportunities.

Maybe we are seeing the death throes of our addiction to fossil fuels. For those concerned about the climate, that would be seriously good news. ■

Fred Pearce is a consultant for *New Scientist*

ONE MINUTE INTERVIEW

I'd like to teach the world...

Apps that tackle child illiteracy in poor countries would be hugely beneficial, so we're running a competition, says **Matt Keller**



PROFILE

Matt Keller is senior director of the Global Learning X Prize, which aims to bring innovative educational technologies to children in poor countries. He was previously involved in the One Laptop per Child initiative

What is the Global Learning X Prize?

It's a \$15 million prize to develop software that takes children from illiteracy to literacy and numeracy in 18 months. In 2016 five finalist teams will each win \$1 million and we'll load their software on to tablet computers, distribute them to different sites in East Africa and test them out. It's probably going to be in Tanzania, and teams will develop software in both Swahili and English. Kids have to learn in their native tongue because that's how you learn how to read. Based on the field tests, in 2019 we'll announce the winning team, which gets \$10 million.

What inspired the competition?

There are around 300 million kids around the world who can't read or write a word after going to school. The enormity of the problem is such that you cannot possibly build enough schools and train enough teachers to teach these kids. Software is the future of learning. It can let kids teach themselves without a grown-up in the equation. The competing teams in this X Prize

will need to come up with something that's independent not only of schools but of adults too.

Can kids really teach themselves?

I'm not a tech utopian, but tablets are so intuitive. When I hand those things to kids, within minutes they turn them on and begin to manipulate the apps, even if they have never seen anything like it. You can envision the day when you give this to a kid and that's her mentor as she goes through primary school – or doesn't. This is what she will learn with. There is going to be an AI-based system that anticipates learning curves and understands what the child doesn't know. And it will allow the child to teach the machine in a way that helps her learn, because teaching is a great way of learning. Forget grown-ups!

Does the One Laptop per Child project hold any lessons?

We had great successes and great failures. The biggest mistake, I think, was that we never spent any time with teachers. They were scared and would lock the laptops away. They didn't want the kids to know more than they did. But where teachers embraced it, the kids took off like rockets. This time we'll work with the local ministry of education and hand the tablets out in villages rather than schools. We'll also talk to every single parent of every kid. I think we'll have 4000 kids in the test group.

What happens after the competition ends?

I think somebody else will develop a learning ecosystem for all ages up to 11 or 12. We'll provide the hardware and build solar charging stations and all that. The big thing is that in four years the cost of a tablet will be close to zero.

What difference will it make, ultimately?

If 170 million kids can learn to read, there would be a 15 per cent drop in poverty rates. When girls, especially, learn to read and write and do basic maths, the economic status of the community is elevated greatly. Basic literacy helps.

Interview by Douglas Heaven

You think there's a multiverse? Get real

Positing that alternative universes exist is just disguising our lack of knowledge about the cosmos, says physicist **Lee Smolin**

COSMOLOGY is in crisis. Recent experiments have given us an increasingly precise narrative of the history of our universe, but attempts to interpret the data have led to a picture of a “preposterous universe” that eludes explanation in the terms familiar to scientists.

Everything we know suggests that the universe is unusual. It is flatter, smoother, larger and emptier than a “typical” universe predicted by the known laws of physics. If we reached into a hat filled with pieces of paper, each with the specifications of a possible universe written on it, it is exceedingly unlikely that we would get a universe anything like ours in one pick – or even a billion.

The challenge that cosmologists face is to make sense of this specialness. One approach to this question is inflation – the hypothesis that the early universe went through a phase of exponentially fast expansion. At first, inflation seemed to do the trick. A simple version of the idea gave correct predictions for the spectrum of fluctuations in the cosmic microwave background.

But a closer look shows that we have just moved the problem further back in time. To make inflation happen at all requires us to fine-tune the initial conditions of the universe. And unless inflation is highly tuned and constrained, it leads to a runaway process of universe creation. As a result, some cosmologists suggest that there is not one universe, but an infinite number, with a huge variety of properties: the multiverse. There are an infinite number of universes in the collection that are like our universe and an infinite number that are not. But the ratio of infinity to infinity is undefined, and can be made into anything the theorist wants. Thus the multiverse theory has difficulty making any firm predictions and threatens to take us

out of the realm of science.

These other universes are unobservable and because chance dictates the random distribution of properties across universes, positing the existence of a multiverse does not let us deduce anything about our universe beyond what we already know. As attractive as the idea may seem, it is basically a sleight of hand, which converts an explanatory failure into an apparent explanatory success. The success is empty because anything that might be observed about our universe could be explained as something that must, by chance, happen somewhere in the multiverse.

We started out trying to explain why the universe is so special, and we end up being asked to believe that our universe is one of an infinite number of universes with random properties. This makes me suspect that there is a basic but unexamined assumption about the laws of nature that must be overturned.

Cosmology has new questions to answer. Not just what are the laws, but why are these laws the laws? How were they chosen? We can't just hypothesise what the initial conditions

“We end up being asked to believe our universe is one of an infinite number”

were at the big bang, we need to explain those initial conditions. Thus we are in the position of a computer program asked to explain its inputs. It is clear that if we are to get anywhere, we need to invent new methods, and perhaps new kinds of laws, to gain a scientific description of the universe as a whole.

Physicist James Hartle has talked about the “excess baggage” that has to be left on the platform before we can board the train

PROFILE

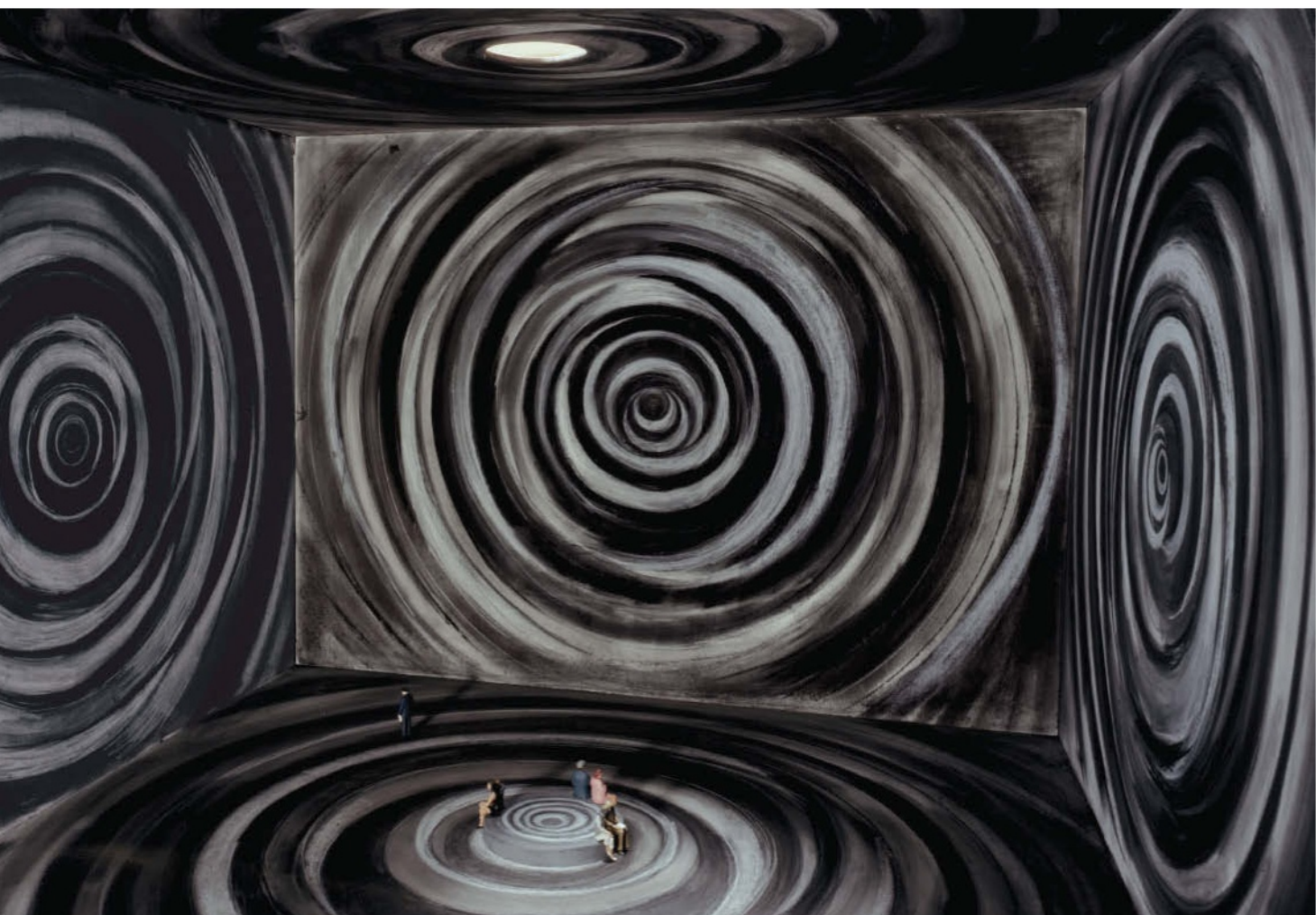
Lee Smolin is a theoretical physicist at the Perimeter Institute for Theoretical Physics in Waterloo, Canada, who focuses on quantum gravity. His new book, *The Singular Universe and the Reality of Time*, which this article is based on, is co-authored with Roberto Mangabeira Unger

to further progress in cosmology. In work together with philosopher Roberto Mangabeira Unger, we believe we have identified several of pieces of this baggage.

The first thing that must be discarded is the assumption that the same kind of laws that work on the scale of small subsystems of the world work, scaled up, at the level of the whole universe. We call this assumption the cosmological fallacy because it leads to a breakdown of predictability – as in the multiverse.

The second piece of excess baggage is the Newtonian paradigm, a method common to classical and quantum mechanics and general relativity. It is used to describe a subsystem of the universe, like a system studied in a laboratory, an atom or a star. This method depends on two elements: the set of possible initial configurations (or states) of the system and a law that specifies how the states change in time. Once we start the system off at an





DAVID DIMICHELE/GALLERYSTOCK

initial state, the law tells us what the state will be at later times. But if the laws and initial conditions are the inputs to the method, they cannot be its outputs too. If we want to understand why the laws hold and how the initial conditions of the universe are chosen, we need a new kind of law and methodology.

The Newtonian paradigm is ideal for describing systems in a laboratory but if we attempt to apply it to the universe, it explains both too little and too much. It fails to explain how the solution to the laws governing our universe is picked from the infinite number of solutions that don't govern anything. But it also predicts an infinite number of facts about an infinite number of non-existent universes. This is one of the reasons why the Newtonian paradigm cannot be applied to the universe as a whole.

These concepts illuminate why the multiverse fails as a scientific hypothesis in spite of the fact that simple versions of

inflation made some predictions that have been confirmed. The idea of inflation is plagued by the need to explain how the initial conditions were chosen. This was done in the context of a methodology that only makes sense when applied to a subsystem of a larger system. When applied to the universe, it forced us to treat the universe as a subsystem of a much larger system: hence we had to invent the multiverse. And thus with an infinite ensemble of unobservable entities we leave the domain of science behind. In some sense, the multiverse embodies the unreal ensemble of all possible solutions to the laws of physics, imagined as elements of an invented ensemble of bubble universes. But this just trades one imaginary, unreal ensemble for another.

Once we accept that we need a new paradigm to do science at the level of the universe as a whole, the next question to ask is what principle that new paradigm should be

Prediction is difficult in a multiverse, taking us out of the realm of science

founded on. This is a question we hope to provoke cosmologists to think about. Mangabeira Unger and I propose three principles, which we argue are necessary to underlie any theory capable of explaining big cosmological questions – like the selection of the laws and initial conditions of the universe – in a way that is open to experimental test.

The first is that there is just one universe. The second is that time is real and the laws of nature are not timeless but evolve. The third is that mathematics is not a description of some separate timeless, Platonic reality, but is a description of the properties of one universe.

These principles take us beyond the Newtonian paradigm and the cosmological fallacy, and are a starting point for exploring the science of the universe as a whole. ■



Adapt first, mutate later

Evolution is meant to start with random mutations. But we may have things the wrong way round, reports Colin Barras



“TO BE honest, I was intrigued to see if they’d even survive on land,” says Emily Standen. Her plan was to drain an aquarium of nearly all the water and see how the fish coped. The fish in question were bichir fish that can breathe air and haul themselves over land when they have to, so it’s not as far-fetched as it sounds.

What was perhaps more questionable was Standen’s rationale. Two years earlier, in 2006, *Tiktaalik* had become a global sensation. This 360-million-year-old fossil provides a snapshot of the moment our fishy ancestors hauled themselves out of the water and began trading fins for limbs. Standen thought forcing bichir fish to live almost entirely on land could reveal more about this crucial step in our evolution. Even if you were being kind, you might have described this notion as a little bit fanciful.

Today, it seems positively inspired. The bichirs did far more than just survive. They became better at “walking”. They planted

their fins closer to their bodies, lifted their heads higher off the ground and slipped less than fish raised in water. Even more remarkably, their skeletons changed too. Their “shoulder” bones lengthened and developed stronger contacts with the fin bones, making the fish better at press-ups. The bone attachments to the skull also weakened, allowing the head to move more. These features are uncannily reminiscent of those that occurred as our four-legged ancestors evolved from *Tiktaalik*-like forebears.

What is really amazing about this experiment is that these changes did not come about after raising generations of fish on land and allowing only the best walkers to breed. Instead, it happened within the lifetime of individual fish. Simply forcing young fish to live on land for eight months was all it took to produce these quite dramatic changes.

We have long known that our muscles, sinews and bones adapt to cope with whatever we make them do. A growing number of

biologists think this kind of plasticity may also play a key role in evolution. Instead of mutating first and adapting later, they argue, animals often adapt first and mutate later. Experiments like Standen’s suggest this process could even play a role in major evolutionary transitions such as fish taking to land and apes starting to walk upright.

The idea that plasticity plays a role in evolution goes back more than a century. Some early biologists thought that characteristics acquired during an animal’s lifetime could be inherited by their offspring: giraffes got their long necks by stretching to eat leaves, and so on. The French naturalist Jean-Baptiste Lamarck is the best-known advocate of this idea, but Darwin believed something similar. He even proposed an elaborate mechanism to explain how information about changes in the body could reach eggs and sperm, and therefore be passed on to offspring. In this way, Darwin suggested, plasticity produces the heritable ➤

variations on which natural selection can work its magic.

With the rise of modern genetics, such notions were dismissed. It became clear that there is no way for information about what animals do during their lifetime to be passed on to their offspring (although a few exceptions have emerged since). And it was thought this meant plasticity has no role in evolution.

Instead, the focus shifted to mutations. By the 1940s, the standard thinking was that animals mutate first and adapt later. A mutation in a sperm cell, say, might produce a physical change in the bodies of some offspring. If the change is beneficial, the mutation will spread through the population. In other words, random genetic mutations generate the variation on which natural selection acts. This remains the dominant view of evolution today.

The dramatic effects of plasticity were not entirely ignored. In the 1940s, for instance, the Dutch zoologist Everhard Johannes Slijper studied a goat that had been born without forelegs and learned to hop around, kangaroo-like, on its rear legs. When Slijper examined the goat after its death, he discovered that the shape of its muscles and skeleton looked more like those of a biped than a quadruped.

Few biologists considered such findings relevant to the evolutionary process. The fact that changes acquired during an animal's lifetime are transient seemed to rule out that possibility. If Standen's better-at-walking fish were bred and the offspring raised in a normal aquarium, for instance, they should look and behave like perfectly ordinary bichirs.

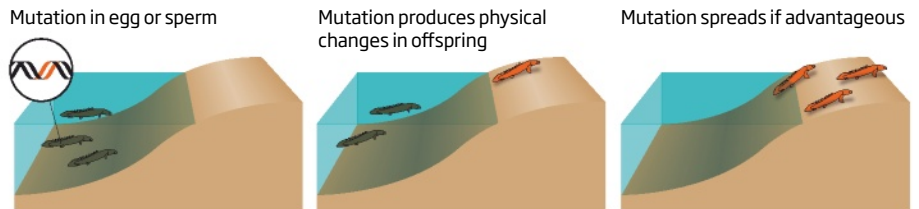
Transient response

But what if the environmental conditions that induce the plastic response are themselves permanent? In the wild, this could happen as a result of alterations in prey animals, or in the climate, for instance. Then all the members of a population would develop in the same, consistent way down the generations. It would look as if the population had evolved in response to an altered environment, but technically it's not evolution because there is no heritable change. The thing is, the only way to tell would be to "test" individuals by raising them in different circumstances.

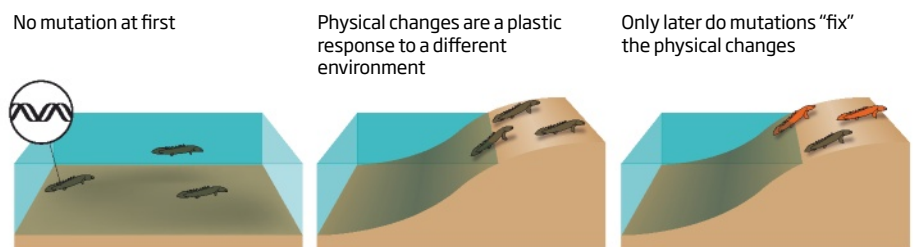
In this way at least, plasticity can allow animals to "evolve" without evolving. The crucial question, of course, is whether it can lead to actual evolution, in the sense

Evolving without evolving

Standard model: mutate first, adapt later



Genetic assimilation: adapt first, mutate later



of heritable changes. "You can plastically induce generation after generation," says Standen, who is now at the University of Ottawa in Ontario, Canada. "At some point, can you remove the environmental conditions that induced the change and have the organisms remain changed?"

The answer, surprisingly, seems to be yes. In the 1950s, British biologist Conrad Hal Waddington showed that it is feasible in an experiment involving fruit flies. Waddington found that when pupa are briefly heated, some offspring develop without crossveins in their wings. He then selected and bred those flies. By the 14th generation, some lacked crossveins even when their pupa were not heated. A physical feature that began as a plastic response to an environmental trigger had become a hereditary feature.

How is this possible? Plastic changes occur because an environmental trigger affects a developmental pathway in some way. More of a certain hormone may be produced, or produced at a different time, or genes are switched on that normally remain inactive, and so on. The thing is, random mutations can also have similar effects. So in an environment in which a particular plastic response is crucial for survival, only mutations that reinforce this response, or at least do not impede it, can spread through a population. Eventually, the altered developmental pathway will become so firmly stabilised by a genetic

No coincidence

Can plasticity explain why evolution repeats itself?

During the last ice age, great ice sheets covered much of Eurasia and North America. As they retreated, they left behind lakes and rivers with no native fish.

Marine three-spined sticklebacks were quick to take advantage, repeatedly colonising these new environments and evolving into the freshwater sticklebacks found today (pictured right). What's extraordinary, though, is that freshwater species that evolved entirely independently of each other are often strikingly similar in body shape, and so on.

This is far from the only example. The cichlid fish of Africa's lakes, for instance, have also evolved along parallel lines in many cases.

The standard explanation for this is convergent evolution: even though

scaffolding that it will occur even without the environmental trigger, making it a permanent hereditary feature.

Waddington called this process genetic assimilation. It may sound like Lamarckism, but it is not. The acquired characteristics don't shape the genetic changes directly as Darwin proposed, they merely allow animals to thrive in environments that favour certain mutations when they occur by chance.

Waddington's findings have been regarded as a curiosity rather than a crucial insight. But in the past decade or two, attitudes have begun to change. One reason for this is a growing appreciation of the flexibility of genes. Rather than being rigidly preprogrammed, we now know that the environment influences many aspects of animals' bodies and behaviour.

Such discoveries have led some biologists to claim that developmental plasticity plays a major role in evolution. A few, such as Kevin Laland at the University of St Andrews, UK, even argue that the conventional "mutate first, adapt later" picture of evolution needs a

rethink (*Nature*, vol 514, p 161). Most biologists have yet to be convinced.

The sceptics point out that genetic assimilation does not overturn any fundamental principles of evolution – in the long run, evolution is all about the spread of mutations, whether or not plasticity is involved. Yes, say the proponents of plasticity,

"The 'bipedal' mice had features like those in our hominin ancestors"

but the key point is that plasticity can determine which mutations spread (*New Scientist*, 12 October 2013, p 33), so its role should be given the prominence it deserves. "Several major recent evolutionary textbooks do not even mention plasticity," says Laland.

It may play a role occasionally, respond the sceptics, but it's a minor one at best. "There is little debate that genetic assimilation can happen," says Gregory Wray of Duke

University in Durham, North Carolina. "But there is unfortunately very little support for its role in nature." This is what makes Standen's work on the bichir so significant. It implicates plasticity in a major evolutionary transition: fish turning into four-legged land animals (*Nature*, vol 513, p 54).

Plasticity will soon be implicated in another major transition too – the one our ancestors made from four legs to two about 7 million years ago. Adam Foster, now at the Northeast Ohio Medical University in Rootstown, has been making mice walk on a treadmill. "I had a custom harness system built so I could modify the load experienced by the hind limbs," he says. Some mice had to walk on their hind limbs, while others walked on all fours. Each mouse exercised on the treadmill for an hour a day for three months, and then Foster examined their skeletons.

He found that the "bipedal" mice had developed longer legs than standard quadrupedal mice, and that their thigh bones had larger femoral heads – the ball in ➤

mutations are random, similar environments produce similar evolutionary results. And there is some evidence to support this view, for instance when it comes to the loss of armour plates in freshwater stickleback species (*New Scientist*, 2 April 2011, p 32).

Strikingly similar

But Mary Jane West-Eberhard of the Smithsonian Tropical Research Institute in Costa Rica thinks parallel evolution happens too often for convergence to be the full explanation. In her 2003 book *Environmental Plasticity and Evolution*, she argues that it happens because similar conditions produce a similar plastic response in the ancestral species. Natural selection then reinforces those trajectories.

If West-Eberhard is right, then at least some of the heritable characteristics seen in living animals originated from the plastic changes

that occurred as their ancestors moved into new environments. And this is actually a testable prediction when it comes to freshwater sticklebacks; marine three-spined sticklebacks are still around, and have changed little since the ice age.

So Matthew Wund at The College of New Jersey in Ewing decided to put West-Eberhard's ideas to the test. With colleagues at Clark University in Worcester, Massachusetts, he set out to discover whether simply allowing marine sticklebacks to eat a diet similar to those of their freshwater cousins as they grew up would lead them to develop similar body shapes too. And it did.

Marine fish raised on planktonic invertebrates from the upper water of deep lakes developed the long snouts of sticklebacks living in lake surface waters. In contrast, marine fish given large invertebrates found at the bottom of shallow lakes developed the stubby snouts typical



SIMON BOOTH/SCIENCE PHOTO LIBRARY

of sticklebacks that live there (*The American Naturalist*, vol 172, p 449).

"We subsequently expanded the experiment to consider not only dietary differences but also habitat," says Wund. The results of those

experiments, published a couple of years ago, also support the idea that developmental plasticity shaped the evolution of sticklebacks as they invaded the lakes left by the retreating ice sheets.

the hip joint. Both features are associated with the transition to bipedalism in our hominin ancestors. Foster's results will be published later this year. "I think Adam's research is really compelling," says Jesse Young, an anatomist at Northeast Ohio Medical University. "As he was getting it going, I was a bit sceptical. You couldn't predict it would reveal anything useful."

While the work of Standen and Foster suggests that developmental plasticity could play a role in major evolutionary transitions, it is only suggestive. Indeed, these studies do not even show that the plastic changes seen in the bichir fish and mice can be fixed by mutations. Demonstrating this kind of genetic assimilation would certainly be tricky, says Standen. It would not be practical with the bichir fish she studied. "As wonderful as they are, they're frustrating fish," says Standen. "They take the better part of a decade to mature, and even then they're really difficult to breed in captivity."

The fossil record is usually no help either. It is possible that some of the changes seen as fish colonised the land were a result of plasticity rather than genetics, says Per Ahlberg of the University of Uppsala in Sweden who studies the transition to land. For Ahlberg, the trouble is that there is no way to prove it. "There's no evidence that will allow us to choose between the two," he says.

More evolvable

Other biologists are more enthusiastic. It has long been suggested that different parts of the skeleton are more plastic and "evolvable" than others, says William Harcourt-Smith of the American Museum of Natural History. "So a foot bone or a hand bone might give you more useful info than a hip bone, for instance."

Work like Foster's could reveal if this is indeed the case and help us interpret the fossil record of human evolution. "These experiments do have validity," Harcourt-Smith says. "They can help us understand whether traits are plastic or not."

Take the honeycomb structure in the heads of our long bones. It is lighter and weaker than it was in our extinct cousins such as the Neanderthals. A study out last month compared the bones of hunter-gatherers and early farmers in North America. It concluded that our bones became weak only when our ancestors' lifestyles changed (*PNAS*, doi.org/xwq). "We could have a skeleton as strong as our prehistoric ancestors," says team member Colin Shaw of the University of Cambridge,



TOBIAS BERNHARD/GETTY

Fiddler crabs can take either side in the debate about the role of plasticity

UK. "We just don't because we're not as active."

It's possible that similar kinds of skeletal structural change seen in prehistory have been misinterpreted as signs of speciation when they really just reflect developmental plasticity, says Shaw – perhaps especially so in hominin evolution. Humans are unique, he points out. "Our first line of defence against environmental insult is culture. When that's not adequate – for instance if the clothing you can make is not good enough to keep you warm – then arguably the second line of defence is plasticity. Only after that fails might you actually get genetic selection."

All this still leaves open the question of whether genetic assimilation can "fix" traits that first appear as a result of plasticity. A decade ago, Richard Palmer at the University of Alberta in Edmonton, Canada, found a way to search for evidence in the fossil record. Most animals have some asymmetric traits. In our case, it's the position of the heart and other organs, which is encoded in our genes. But in other species, asymmetries are plastic. For instance, the enlarged claw of male fiddler crabs (pictured above) is as likely to be on the left as on the right.

What Palmer showed by examining the fossil record of asymmetry in 68 plant and animal species is that on 28 occasions, asymmetries that are now hereditary and appear only on one side started out as non-

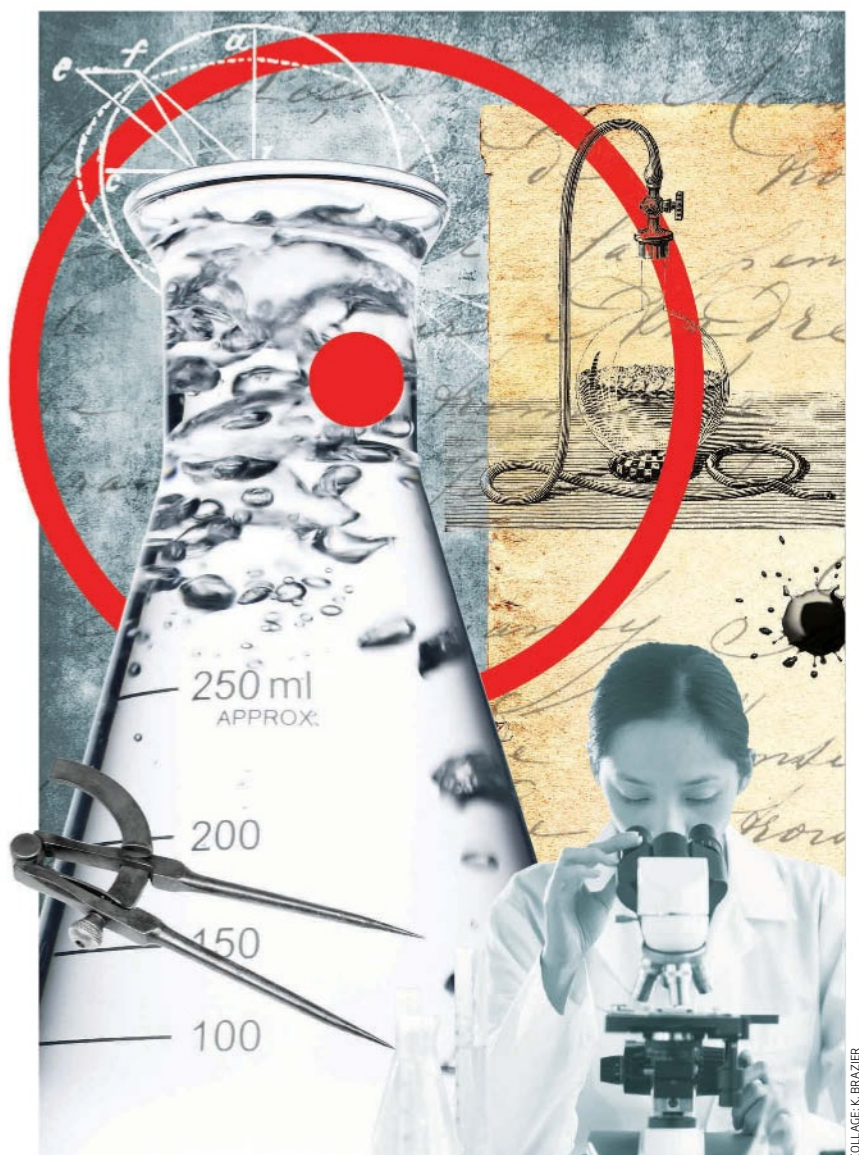
hereditary asymmetries that appeared on either side (*Science*, vol 306, p 828). "I think it's one of the clearest demonstrations that genetic assimilation has happened and that it is more common than expected," says Palmer.

There is a caveat here, though. The ancestral non-hereditary asymmetries may have been a result of random genetic noise, says Palmer. So while his work does show genetic assimilation in action, it was not necessarily fixing traits due to developmental plasticity.

There is no simple way to prove the evolutionary importance of developmental plasticity, says Mary Jane West-Eberhard of the Smithsonian Tropical Research Institute in Costa Rica, whose work has been particularly influential. "Evolutionary biology that is concerned with evolution and speciation in nature necessarily depends on indirect proof – an accumulation of facts that support or deny a hypothesis," she says.

At the moment, the facts that are accumulating seem to support the hypothesis. Expect lots more results soon: Standen's success is inspiring others. "I've already had people ask me what other critters we could try this on," says Standen. "Everybody is friendly and excited and interested. It's fun – it's the way science should be." ■

Colin Barras is a freelance writer based in Ann Arbor, Michigan



DO IT AGAIN

What can we find out by re-enacting the science of yesteryear, asks Richard Webb

SCIENCE is a forward-thinking sort of discipline. While displaying due reverence for the great achievements of its past, it is not generally inclined to revisit them. What is cutting-edge is what's happening now.

It was also what was happening then, and a growing number of researchers are finding it worth their while to recreate the science of the past, from the convoluted processes of alchemists seeking to make gold to pioneering experiments with electricity. For historians, the approach provides a new way of getting to grips with how we used to acquire knowledge, one that simply poring over written records can't.

But it can yield revelations for scientists, too: insights into the minds of great practitioners of the past, a better understanding of why science took the path it did, or the rediscovery of long-lost knowledge. Remaking the science of the past can still inform the science of today.

LETTING OFF STEAM

While researching a book on the history of the thermometer, Hasok Chang found himself reading accounts of old experiments on boiling water. Soon he had steam coming out of his ears. "I'm going, these guys must be crazy or badly mistaken or taking the mickey," says the historian of science at the University of Cambridge.

What raised his hackles was the repeated assertion that water could boil at temperatures other than 100 °C. There was 101 °C, 103 °C - even, in one account of work by the 18th-century Swiss scientist Jean-André de Luc, 112 °C. The researchers involved were reputable, and the procedures they followed seemed legitimate. So what was going on?

There was only one way to find out. "Within minutes of stepping into the lab I found out they were right," says Chang. Historians of science often speak of the concept of "tacit" knowledge - knowledge considered so common that it wasn't worth writing it down. What Chang seemed to have rediscovered, on the other hand, was knowledge that was once known, but has since been forgotten.

Shake it

We're familiar with the idea that water boils at lower temperatures when air pressure is reduced, for example on mountaintops. But other factors are also relevant: the speed of heating, the shape and material of the container and the amount of air and other substances dissolved in the water. De Luc achieved his 112 °C by the admittedly extreme measure of carrying a container of water around for four weeks, shaking it to rid it of dissolved air.

Such complexities are apt to be ignored. "You don't want to spend time confusing your students on where water boils when you want to move them on to quantum mechanics," says Chang. "So you get a Mickey Mouse version of the story when you're 10 and then it disappears." He thinks that is dangerous. "It provides a false sense of security about scientific knowledge."

Reviving such ideas is certainly timely. With the increasing emphasis on energy efficiency, engineers are beginning to look again at basic, overlooked thermodynamic effects: how the presence of nanoparticles can increase the flow of heat into water, for example, providing a route to more efficient refrigerators and steam turbines.

Chang has since moved on to recreating some of the first experiments on electrochemical batteries from the early 19th century. He thinks many other neglected effects could be lurking in historical experiments that were never repeated. "These experiments are not only recovery, but an extension of the past," he says. "We are discovering phenomena they didn't write about." ➤

MORE THAN MAGIC

"Then take all the rest of the aforesaid black Feces or black Dragon, and spread them somewhat thin upon a clean Marble, or other fit Stone, and put into the one side thereof a burning Coal, and the Fire will glide through the Feces within half an Hour, and Calcyne them into a Citrine Colour, very glorious to behold."

It doesn't exactly sound like science, and this extract from *The Bosome Book of George Ripley*, a mid-15th-century text, illustrates alchemy's image problem, says Jennifer Rampling, a historian of science at Princeton University. Today we think of the quest to turn base metals into gold as not just misguided but positively mystical. "We tend to associate it with robes and funny hats," she says.

That is a travesty, she thinks. Alchemy goes beyond what we think of as modern chemistry by incorporating elements from natural philosophy, theology and metaphysics, but that doesn't mean we should write it off. "In every field there are cranks. But a lot of alchemists were very serious and rational about what they did," says Rampling. "Essentially, I am interested in what these scientists thought they were doing."

Glorious transmutation

Follow some alchemists' instructions carefully, and a lot of what you read begins to make perfect sense – even if our modern interpretations might be different. Take the "black Feces".

Working at the University of Cambridge in 2012, Rampling followed Ripley's convoluted recipe, and saw exactly the glorious transmutation described. "You do get this unpromising black powder igniting and see this beautiful golden colour spreading over the surface," she says. It's just not the gold of alchemists' desire: it is finely ground lead oxidising into yellow lead(II) oxide, or litharge.

Lawrence Principe of Johns Hopkins University in Baltimore, Maryland, has made similar discoveries, for example, recreating a "tree of gold" described in an alchemical text using a mix of gold and mercury. In his book *The Secrets*



THE BOSOME BOOK OF GEORGE RIPLEY

Containing His Philosophical Accurtations in Making the Philosopher's Mercury and Elixirs.

"First take thirty pounds weight of sericon, or antimony, which will make twenty-one pounds weight of gum, or near thereabouts, if it be well dissolved and the vinegar is very good; and dissolve each pound thereof in a gallon of twice distilled vinegar. When cold again, and, as it standeth in dissolution in a fit glass vessel, stir it about with a clean stick very often every day, the oftener the better; and when it is well molten to the bottom, then filter over the said liquors three several times, which keep close covered, and cast away the fæces, for that is superfluous filth which must be removed and entereth not into the work, but is called Terra damnata..."

of Alchemy, he argues that modern chemistry owes much to alchemists. Their achievements become all the more remarkable, says Rampling, once you take into account the impurity of some of their starting materials and the lack of basic equipment such as thermometers to monitor reaction temperatures.

Rampling is now getting Princeton science undergraduates to perform alchemical tricks for themselves, in the hope of opening their eyes to different ways of thinking. "My hope is that they will be better scientists because they have thought clearly about past science," she says.





COLLAGE: MICHELLE THOMPSON; PHOTOGRAPHS: DE AGOSTINI/G. DAGLI ORTI/GETTY/SUPERTOCK

BLASTS FROM THE PAST

Behind an anonymous door at the bottom of a multistorey car park in the north of England, I am politely asked to surrender my phone and submit my bag for searching. I am reminded that my video camera should be used to record only the agreed subject of my visit – and not doors or entranceways, under any circumstances.

Once I am through an airport-style security arch and another set of secure doors, the reason for the wariness becomes clear. I am standing in a vast, windowless underground storeroom, its walls and shelves stacked with thousands upon thousands of guns.

This is the UK's National Firearms Centre. Imposing as its repositories are, they are not why I am here. Guns mean gunpowder, and I am due on the centre's firing range to witness an attempt to reproduce experiments from over three centuries ago, aiming to find out exactly how gunpowder worked.

Unexpected bangs

The tests are the baby of Haileigh Robertson, a PhD student in the history of science at the University of York, UK. Unnervingly, she admits she is not entirely sure how they will pan out. What's certain is that if there are to be any large bangs, this would be a very good place to keep them quiet.

Gunpowder, a mixture of charcoal (carbon), sulphur and saltpetre (potassium nitrate), was discovered in 9th-century China, and spread steadily westwards over the following centuries. By the 17th century, its use in cannons and muskets was well established in Europe. But no one quite grasped how it worked. "It was a substance that everyone knew and appreciated. It was incredibly powerful and useful and in very high demand, but at the same time we didn't really understand it," says Robertson. "It was often referred to as magic."

Even the process of making the stuff was steeped in mysticism. Saltpetre was often sourced from residues in animal dung, and there was little in the way of quality control. One batch might give a big bang for your buck, the next barely a whimper.

This was where gunpowder encountered the verve of the first experimental scientists of the Age of Enlightenment. Their mantra was "knowledge is power", and there was no more obvious thing to test than gunpowder. Starting in the 1660s, a series of experiments under the aegis of London's newly

established Royal Society began. Gunpowder became a proving ground for emerging ideas about combustion and matter itself – the beginnings of chemistry as we know it. Better control over how gunpowder worked would, it was hoped, lead to its exploitation beyond the military realm.

Contemporary accounts of these experiments do exist, but are frustratingly incomplete. “Documents often only tell us about experiments that work, not about the challenges,” says Robertson. The Royal Society records do show that their testing apparatus, a device called an epruvette, kept on breaking, sometimes because the experimenters put too much gunpowder in it. But really getting to grips with how these experiments worked means getting your hands dirty.

Testing time

Today Robertson is aiming to repeat the epruvette work using a replica device built by historian Steven Walton of Michigan Technological University in Houghton. It has two vertical supports about 60 centimetres high, with a post suspended between them. Attached to the bottom of the post is a brass lid which sits atop a small powder chamber and priming pan.

When gunpowder is ignited in the powder chamber, the force of the explosion should propel the brass lid and post up past a series of ratchets that flip up, and then catch the lid as it begins to fall. The height the lid reaches is a measure of the gunpowder’s relative potency.

Robertson’s collaborator Peter Smithurst, an emeritus curator of firearms at the National Firearms Centre, first packs the chamber with modern “black powder”. Technician Trevor Weston approaches cautiously with a long lit taper. I stand ready with the video camera. “I wouldn’t want to stand too close,” says Robertson, “until we know what it does.”

What it does, besides make an almighty flash and bang, is hard to discern at first. But when the smoke disperses, the lid is balancing 13 ratchets up, half a metre off the floor. So far, so good.

Less successful are gunpowder mixtures prepared using old recipes by Smithurst, a trained chemist. There is the odd fizzer like a Roman candle, and quite a few proverbial

“What it does, besides make an almighty flash and bang, is hard to discern at first”



flashes in the pan. No one is sure why these mixtures don’t work as well – perhaps the modern stuff is finer-grained, with a larger surface area to encourage ignition. Or maybe the samples have got damp somehow.

Archaeologists and historians alike want to understand the factors affecting the potency of early gunpowder. The power and range of early guns depended on the energy it could generate, so gunpowder influenced not only the design of cannons and armour, but also the evolution of battlefield tactics.

By reproducing these experiments we get a feel for what was possible – and an idea of the frustrations. Historically, we know gunpowder research was a slow burner: investigations of its action became a regular feature of the Royal Society’s house journal, *Philosophical Transactions*, during the 18th century.

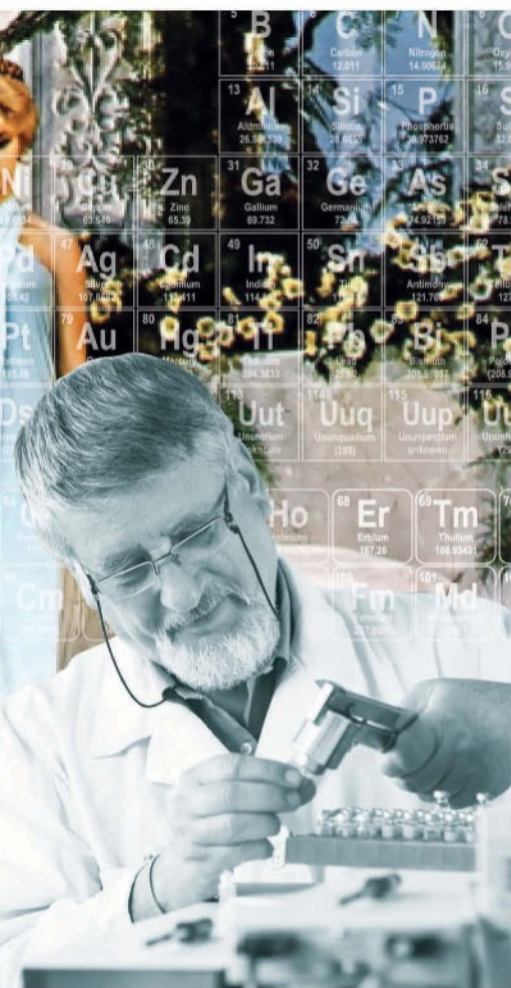
Sadly, after a few more whimpers rather than bangs, I have to leave the firing range. On returning to London, I find an email from Robertson: drilling a larger borehole from the priming pan to the powder chamber had done the trick for the vintage powder formulations. Had the historical greats still been around, they might have been able to tip us off about that. But by doing things as they themselves did, we can at least meet them halfway.

SPARK OF GENIUS

What is light? In the 1860s James Clerk Maxwell used his unified theory of electromagnetism to show that light travelled at the same speed as electromagnetic waves. So were the two phenomena the same thing?

It was only two decades later that a series of – literally – brilliant experiments by the German physicist Heinrich Hertz showed that they were. Starting in 1886 at the University of Karlsruhe, Hertz set up an oscillator made of polished brass knobs connected to induction coils. Given a sufficiently high driving voltage, sparks would leap across a gap in the circuit. If light and electromagnetic waves were the same thing, waves would be generated every time a spark appeared and be registered by the induction coil. And so they were.

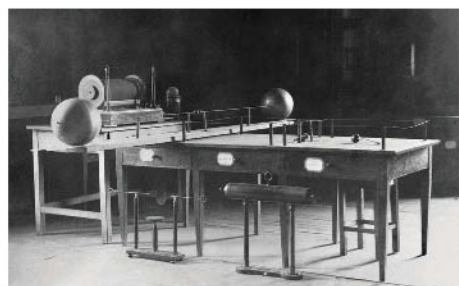
There are many reasons to reproduce Hertz’s experiments, says physicist and historian of science Roland Wittje of the University of Regensburg, Germany – not least



COLLAGE: K. BRAZIER; PHOTOGRAPHS: 20TH CENTURY FOX/THE KOBAL COLLECTION; UNIVERSAL HISTORY ARCHIVE/UiG/BRIDGEMAN

that they are great fun. "It's not very easy to produce the spark, but it is always exciting when you do," he says.

But the difficulty in getting Hertz's contraption to work also makes plain how groundbreaking his ideas were, and how hard they were to prove with the tools then available. That gives a new appreciation of his position in the history of science, says Wittje. "When you look backwards it is very clear what the outcome should be," he says. "The biggest challenge for a modern physicist doing this is to forget modern physics."



PHOTODEUTSCHESMUSEUM

WASH LIKE AN EGYPTIAN

Peer pressure led Laurence Totelin to try to recreate a beauty regime as Cleopatra might have known it. A classicist at Cardiff University, UK, specialising in the history of medicine, she often gave talks on ancient cosmetic recipes. Some, like modern-day beauty products, claimed to have a celebrity endorsement – often of Egypt's famously milky-skinned queen.

"People would always say, have you tried what you are talking about?" Totelin says. "I would give convoluted explanations like, it's very difficult to get the ingredients, we can't judge the efficacy, is it safe, and so on. I could tell that wasn't cutting it."

A period of maternity leave finally gave her the opportunity she needed. After much tinkering, she has managed to recreate ancient soaps, skin creams and sunscreen. Among her favourites is a soap which "the Patrician Pelagia used to make her face shine", according to the sixth-century writer Aëtius of Amida. One of the more detailed recipes she tried, it calls for white lead and deer marrow, among other things (see right). Out of a mixture of squeamishness and common sense, Totelin replaced these with zinc oxide and cocoa butter.

Ancient hair gel

Such liberties might dismay purists, but for Totelin the aim is not to reconstruct the past exactly. "I get a sense of how things look and how they work, whether it is possible to make things," she says. Up until recently, she points out, even culinary recipes did not include much detail, relying instead on tacit knowledge every reader was assumed to have. By following the recipes and seeing what does and doesn't work, she hopes to gain a better idea of what counted as common knowledge when the recipes were set down.

It wasn't just Cleopatra who set great store by her appearance. Archaeologists have found hair gels on mummified bodies in ancient Egyptian tombs, and even uncovered traces of soap-like cosmetics in reed containers found alongside bodies. Analysis of this shows the presence of lead palmitate and stearate, and also a lead salt called phosgenite. Were these compounds an intended by-product of manufacture, or did they form as the soap degraded over thousands of years? By recreating ancient recipes, we may begin to find answers to such questions.

The patrician Pelagia's soap turned out to be more like a white, unscented cold cream. It did feel rather good – even though Totelin opted to test it first on her hands, not her face. Totelin's ancient cosmetics certainly make a talking point on the conference circuit. "Now I have things to show to people," she says. ■

Richard Webb is *New Scientist's* deputy feature editor



LAURENCE TOTELIN

CELEBRITY SOFT SOAP

Soap the patrician Pelagia used to make her face shine:

Gallic soap, 6 ounces; starch, 1½ ounce; white lead, 1½ ounce; mastic, ½ ounce; deer marrow, 1 ounce; white native sodium carbonate, 4 pastilles; white wax, 3 ounces. Soak the soap beforehand in water in a small jar for five days, changing the rain water every day and filtering the soap. After that, on the sixth day, put the soap in a new cooking pot with the rain water; place on coals, on a low heat, until the soap has melted. Then sprinkle with the wax and the marrow, and when they are dissolved, take the frying pan and stir well with a spittle and sprinkle the mastic and the starch, ground beforehand. Then add the white lead (ground beforehand in some water) in a small dish and beat up with the hand vigorously. Then place in a new jar and use generously.

DARK RITES

Logic and reason may set our species apart, but so does a penchant for nonsensical rituals, finds Dan Jones





The people of Shetland dress up as Vikings every year and burn a replica longship

It's cold and dark in Shetland at this time of year, but nobody is hibernating. Instead, the residents of these subarctic Scottish islands are furiously busy putting the final touches to their annual festival, Up Helly Aa. Come Tuesday 27 January, those living in the capital, Lerwick, will enjoy a full day of festivities culminating in a torchlit procession of some 1000 "guizers" – men disguised as Vikings – and the burning of a replica longship.

The festival is relatively young, having begun in the 1880s, but that doesn't prevent Up Helly Aa from being infused with mystery. For a start, there's the name: nobody knows quite where it came from or what it means. Then there are all the strange and intricate rituals to be followed. And finally, there is the small question of exactly what Up Helly Aa is supposed to celebrate.

Although unique to Shetland, the festival is not unusual as rituals go. Rituals are often complex and nonsensical. Yet every culture has them – and for good reason. "Rituals provide a very visible means of identifying who is a group member and who isn't," says developmental psychologist Cristine Legare from the University of Texas at Austin. "They help define us as a group, reflect our group values, and demonstrate shared commitment to the group." For a species like us, that is dependent on social support, this is crucial for survival – so much so that, Legare believes, we are born with a mind for ritual. Her studies with children suggest that the nonsensical nature of ritualistic behaviour triggers a mode of thinking distinct from the logical cause-and-effect approach. This ritualistic thinking, in turn, prompts us to copy actions that make no apparent sense.

Rituals come in a bewildering variety, and that makes it difficult to define exactly what counts as one (see "Ritual demarcations", page 38). However, they do have certain characteristics in common. In particular, they tend to involve several discrete, specific steps that follow a defined script (see "Complexity rules", page 39), and the actions are often hard to make sense of in terms of cause and effect, unlike other multi-step behaviours such as changing a tyre or baking a cake. "To an outsider, ritual behaviours seem utterly useless," says psychologist Matt Rossano at Southeastern Louisiana University in Hammond. "You have to do things in a very rigid, arbitrary way, but this is completely tangential to achieving any practical goal."

It is this "causal opacity" that led Legare to suspect a connection between rituals and a puzzling phenomenon observed by child ➤

“Children copy apparently aimless sequences of actions more faithfully than ones with a clear goal”

RITUAL DEMARCATIONS

All rituals are social conventions: activities based on rules that groups and cultures develop in order to regulate social behaviour. But not all social conventions are rituals. Conventions such as the side of the road you drive on and the language you speak have no ritualistic component; they are simply solutions to problems of coordination. So what makes a social convention ritualistic?

In fact the dividing line is blurred, and ritualistic behaviours falls along a spectrum. At one end, there are things like social etiquette. Whether you greet a friend with one kiss on the cheek, or two, or plant your lips on their nose, is entirely arbitrary. But greet and kiss incorrectly and you mark yourself out as an outsider, someone who doesn't get how “we” do it. Such conventions are still too simple to make the grade as true rituals, though.

Activities like the Japanese tea ceremony or traditional Chinese New Year celebrations are more ritualistic. These comprise a highly formalised mix of custom and etiquette that

proceeds through a series of ritualised steps. But such activities are too purposeful to make it as full-blown rituals, which are set apart by their lack of clear purpose. They tend to comprise a complex series of actions that cannot be understood in terms of cause and effect and are performed to a script.

Some of the most significant rituals mark major life events and transitions, including birth, entry into adulthood, marriage and death. The most powerful tend to be performed in synchrony with other people or repeated many times to create a sense of cohesion. Group bonding is amplified even more by making rituals physically or emotionally intense – through the element of pain, fear or the use of hallucinogenic drugs, for example. Among the most viscerally compelling rituals are the many traditional initiation rites marking entry into manhood. These include such delights as bleeding the penis with pig incisors, and dangerous bungee-like jumps using inelastic vines.

psychologists in experiments over the past three decades. Show a child how to perform some action that they haven't seen before, and they will faithfully replicate not only the steps required to achieve the goal, but also superfluous ones. Why they do this is a puzzle, especially as other animals do not. It could be a clever strategy: the human world is so complex that it makes sense for kids to copy everything until they have time to work out what is necessary. But, wondered Legare, what if children can identify actions as causally opaque? If so, perhaps their brains see them as a cue to switch from normal reasoning to a “ritual stance” in which they interpret the behaviour of others as social signals, and go out of their way to copy them.

Lure of the illogical

In 2010, Legare began testing her idea. The first clue she was on to something came with the discovery that children copy apparently aimless sequences of actions more faithfully than sequences that move towards an obvious goal. In a range of experiments, she and her colleagues found the effect applied to children as young as 3, and the ability to emulate the actions improves as children get older. A causally opaque sequence might include actions such as picking up a blue cube, tapping it twice against a green peg on a wooden pegboard, putting the cube back in its original position, and then pressing your hands together. A more comprehensible series of actions with the same objects might end with the cube being placed inside a box, as if that was the goal.

The next step was to test whether any apparent social dimension associated with ritualistic behaviour influences a child's attempts to copy. Legare, together with Austin colleague Patricia Herrmann, psychologist Paul Harris at Harvard University and anthropologist Harvey Whitehouse at the University of Oxford, showed kids videos of people manipulating wooden pegs to no obvious purpose. There were 259 children, aged from 3 to 6 and split into four groups. Group one saw one person doing the actions, and watched the video twice. Group two saw videos of two people performing the same manipulation in succession. Group three watched two people performing the actions in synchrony. And group four saw the synchronised demonstration video twice.

The accuracy with which the children subsequently copied the nonsensical actions



A tea ceremony, unlike most rituals, has an obvious purpose

HORACE BRISTOL/CORBIS



NIGEL PAVITT/JAL/CORBIS

All human societies have rituals, which define and bond them

increased progressively from groups one to four (*Cognition*, vol 129, p 536), supporting Legare's idea. "Children are driven to copy behaviours in their group," says Nicole Wen, a doctoral student in Legare's lab. "Seeing multiple people doing the same thing provides a cue that it's a social convention, which enhances that drive to imitate."

If children copy ritual behaviours because these signal social affiliation, then feelings of being excluded could heighten the drive to copy. To test this idea, Legare, her colleagues Rachel Watson-Jones and Jennifer Clegg, and Whitehouse, primed kids aged 2 to 6 to think about ostracism, if only subconsciously, by watching an animation showing a group of three geometric shapes "playing" together and "ignoring" a fourth shape. Next, they watched either a video showing a goal-oriented series of actions or one where the actions were causally opaque. The children who had seen the spectre of ostracism copied more accurately, and the effect was especially marked when ritualistic actions were involved (*Evolution & Human Behavior*, vol 35, p 204). Ongoing research seems to suggest that this effect is even stronger when kids are ostracised from a group with which they identify – even merely one that they have been assigned to for the purposes of the experiment.

"Anthropologists have been studying rituals for a long time, usually looking at their social, symbolic and cultural significance," says Rossano. But now the tools of developmental psychology are being brought to bear on ritual and focusing on children. "Legare's innovative studies add a new and important piece to the research puzzle," he says.

Psychologist Daniel Haun at the Max Planck Institute for Psycholinguistics in Leipzig, Germany, agrees, describing her work as "terrific". He says we have a deep tendency to like people who are like us, and shared social conventions are an excellent way of creating similarity. "In a world in which people preferentially trust, trade and interact with those perceived as being similar, it makes sense to do what others are already doing," he says. But rituals go beyond other social conventions. "They're a special subset." What's striking about rituals is not just their power to signal group membership, but also to create the social glue that binds people into groups.

Creating togetherness

Legare and Wen have recently investigated this aspect of ritualistic thinking too. They recruited 81 kids aged 5 to 8, split them into groups and got them to make necklaces. Members of two groups spent 7 minutes making necklaces in synchrony with other group members, following a script such as "first we add a green heart, then an orange square", and so on. Another two groups were simply given beads and allowed to spend 7 minutes stringing them up however they wished. After making necklaces three times a week for two weeks, the children were quizzed about how connected they felt – whether they wanted to stay in their group, for example, and whether a new kid would prefer being in their group to joining another. Those who had worked together ritualistically reported a greater sense of connection to their group than those who made freestyle necklaces.

COMPLEXITY RULES

In Brazil you can buy "recipes" for rituals at neighbourhood shops. *Simpatias* are designed to be performed at home to help achieve a particular goal such as finding a romantic partner or treating illness. A *simpatia* for getting a new job might run as follows:

"During the full moon, take the jobs page out of a newspaper, fold it four times, and place it on the floor with a small white candle surrounded by honey and cinnamon, while imagining yourself in a new position with good pay. Then, bury the candle stub and paper under a plant and water it daily."

It's hard to see why these steps would elicit the desired effect, but that may be part of the appeal. When Andre Souza at the University of Alabama in Tuscaloosa and Cristine Legare from the University of Texas at Austin asked Brazilians to rate numerous *simpatias* according to their perceived effectiveness, it emerged that the more steps the *simpatias* had and the more specific these were, the higher they scored (*Cognition*, vol 124, p 1). Rituals the world over tend to share these characteristics of being complex and hard to make sense of. In fact, this may be the key to understanding how we think about them. It could also explain one of the most puzzling aspects of child psychology (see main story).

Rituals are often associated with religious beliefs and practices, but there's nothing inherently religious about the drive to soak up and copy rituals, as Legare's studies show. She sees rituals as a kind of cultural gadget to help groups survive. "Collective rituals are public signals that you are committed to the group," she says, "which facilitates cooperation with the group and creates a sense of shared purpose." Students at some universities are willing to endure humiliation and abuse to gain membership of select fraternities. Sports teams perform their own characteristic routines to psych themselves up for their next challenge. And in the military, nearly every aspect of daily life becomes a sort of collective ritual – from how beds are made to drills on the parade ground.

Even though they are ubiquitous, rituals often seem arcane, or even daft, to the uninitiated. Yet this is where they get their power. "For observant children, it's the useless things we do that tell them the most about how to be a good group member," says Rossano. ■

Dan Jones is based in Brighton, UK

Trapped in the machine

Let's pit the people power of cryptocurrencies against big data, says **Jonathon Keats**

The Black Box Society: The secret algorithms that control money and information by Frank Pasquale, Harvard University Press, \$35/£25.95

Cryptocurrency: How bitcoin and digital money are challenging the global economic order by Paul Vigna and Michael J. Casey, Bodley Head, £20

AS THE second biggest discount retailer in the US, Target has more than 100 million customers. Each is assigned a unique identification number, allowing Target to track their purchases and tempt them with targeted advertisements.

The same data permits Target to perform a more startling feat: by correlating purchasing patterns with its online baby registry, the company can determine which products pregnant women typically buy each trimester. First come the vitamin supplements, then cotton balls and unscented soap. Just by studying these buying patterns without any knowledge of the person, Target can also accurately predict when a customer is pregnant.

For Target, this kind of consumer data mining is a marketing triumph. For Frank Pasquale, writing in *The Black Box Society*, it's a travesty. Pasquale is a law professor at the University of Maryland, and he sees Target's intrusion as part of a larger failing to protect privacy.

As he writes: "Important corporate actors have unprecedented knowledge of the minutiae of our daily lives, while we know little to nothing about how they use this knowledge to influence the important decisions that we – and they – make."

These asymmetries surround us. Pasquale is equally outraged by the hidden systems used by



credit agencies to determine people's credit ratings, and the proprietary software human resources departments use to make hiring decisions. He also rails against the secrecy surrounding how Apple chooses its apps, and how Google's search algorithms do their page ranking.

"Just by studying buying patterns, US retailer Target can predict when a customer is pregnant"

All of these are what he calls "black boxes", by which he means that they are constantly recording us while being inscrutable in their own right.

Given his sheer range of targets, Pasquale faces a formidable

challenge in presenting a coherent argument. He attempts it by showing how powerless we are to prevent companies from collecting data about us, and how easily the information can be abused.

Many of the numerous cases he presents have received media attention: prospective employers who run background checks by scrutinising Facebook, for example, online retailers that tweak prices based on shoppers' addresses, credit card companies hiking interest rates when they discover cardholders who seek marriage counselling, and banks that misrepresent risky investments to unsuspecting clients.

While grouping this together is a dramatic way to conjure a

Nothing is sacred for retailers mining your every purchase

trend, defining abuse so broadly undermines any serious call to action. Yet Pasquale is undeterred, urging government regulation and demanding transparency about data collection so regulators can dictate how information may be used. From predictive marketing to predatory banking, the law professor's remedy is legal action.

Pasquale does fleetingly acknowledge an alternative. Almost in passing, he mentions "digital self-protection" – his catch-all for everything from cyber-hygiene on Facebook to internet anonymity on Tor, an "onion network" that randomly

relays deeply encrypted data through thousands of decryption nodes to prevent eavesdropping.

But he quickly rejects such measures as ineffective, inaccessible and/or potentially criminal. He writes: "I wouldn't want so-called 'cryptocurrencies' hiding ever more money from the tax authorities and further undermining public finances." For a book purporting to be about the interrelationship between privacy and technology, this is a disappointingly glib dismissal.

Admittedly, cryptocurrencies such as bitcoin aren't easily understood, a problem that has contributed to their questionable reputation. But in *Cryptocurrency*, *Wall Street Journal* writers Paul Vigna and Michael J. Casey do an

everyone would be kept honest – and nobody would spend money they didn't have – because all credit and debt would be tracked in an open ledger called the blockchain. All transactions between accounts would be known to everyone. Only the account holders would remain anonymous, controlling their accounts cryptographically.

Nakamoto's plan worked well enough that there are more than 5 million bitcoin accounts globally, and hundreds of cryptocurrencies use variations on the bitcoin protocol. There has also been no shortage of scandal, such as the hacking of bitcoin exchange Mt. Gox and theft of bitcoins, and the shutdown of Silk Road, a bitcoin-based online emporium that specialised in illegal drugs. Vigna and Casey show in detail how such scandals have contributed to bitcoin's notorious fluctuation in value, without having any impact on the trustworthiness of the blockchain ledger itself.

As financial writers, Vigna and Casey are most interested in how cryptocurrency can fix our global financial system, making the movement of money more efficient and curbing the power of banks. Yet, as they observe, the greatest cryptocurrency breakthrough is to free people from "the tyranny of centralized trust". The blockchain concept can support anything from personal loans to retail sales to contractual agreements, always preserving personal privacy.

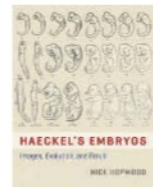
Bitcoin is still a small player in the global economy, and so-called blockchain 2.0 applications are fledgling, but that can change if we so choose, just as we can decide about government regulation of technology. And if cryptocurrency does transform the power dynamics of finance and commerce, many of the injustices and indignities raised by Pasquale could simply become irrelevant. ■

Jonathon Keats is an experimental philosopher and conceptual artist

Drawn-out lies

Exquisite or not, there can be a dark side to scientific illustrations, finds **Matthew Cobb**

Haeckel's Embryos: Images, evolution, and fraud by Nick Hopwood, University of Chicago Press, \$45



IT'S embarrassing but true: some of the most influential drawings in the history of biology are

wrong, exaggerated to fit a thesis.

As we discover in *Haeckel's Embryos*, German biologist Ernst Haeckel included illustrations of the embryological stages of vertebrates in a series of books published between 1868 and 1908. Fudging the data, he placed the drawings into a comparative grid, highlighting similarities between species and blurring differences. The results are highly inaccurate.

Haeckel wanted to convince his readers that all vertebrates share a common ancestor, and that, as he put it, "ontogeny recapitulates phylogeny" – our embryonic development repeats our evolutionary past. This aphorism was soon disproved, but the use of

Haeckel's drawings persisted, particularly in education. There were waves of criticism, from the 1870s when the drawings were published, up to 1997 as Haeckel's "fraud" was rediscovered and exploited by creationists.

In this sumptuous book, Nick Hopwood, a science historian, examines how and why Haeckel made his drawings, and the use made of them since. His clever detective work takes him into the Haeckel archives in the German town of Jena, discovering the original drawings and even the woodblocks. At the other end of the story, he explores how Haeckel's drawings appeared in postwar textbooks in the UK and the US.

Stunning illustrations show the way the images have been copied and reinterpreted from the late 19th century on, and insights from writers shed a fascinating light. For example, Scott F. Gilbert, author of a 1985 developmental biology textbook, inadvertently used Haeckel's images.

Ironically, although Haeckel's drawings are used only as relics now, modern molecular genetic studies show that his fundamental point – that there are important similarities between different vertebrate embryos – seems less mistaken, even though his diagrams are profoundly wrong.

Hopwood's excellent, thought-provoking book makes us ponder how these erroneous illustrations acquired their iconic status, and, above all, it shines a spotlight on the power of drawings to influence our thinking. ■

Matthew Cobb is professor of zoology at the University of Manchester, UK



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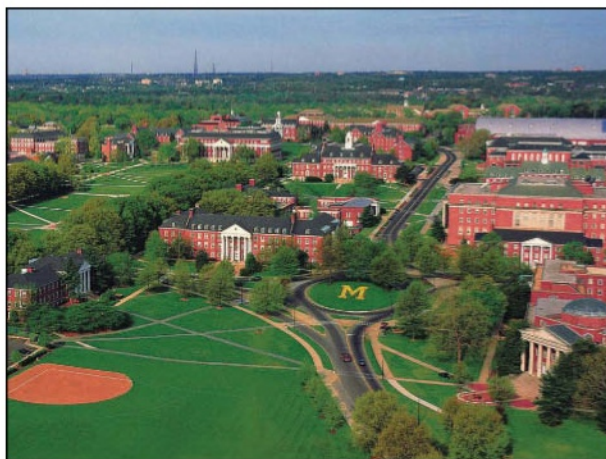
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DIVERSITY IN SCIENCE

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INFECTIOUS DISEASES

Investigators in the Pathogenesis of

Infectious Disease: Five-year awards provide \$500,000 for opportunities for accomplished investigators at the assistant professor level to study infectious disease pathogenesis, with a focus on the intersection of human and microbial biology. The program is intended to shed light on the overarching issues of how human hosts handle infectious challenge.

INTERFACES IN SCIENCE

Career Awards at the Scientific Interface:

Five-year awards provide \$500,000 to bridge advanced postdoctoral training and the early years of faculty service. These awards are intended to foster the early career development of researchers with backgrounds in the physical/mathematical/computational/engineering sciences whose work addresses biological questions. BWF has moved to a self-nomination format for this award.

POPULATION AND LABORATORY BASED SCIENCES

Institutional Program Unifying Population and Laboratory Based Sciences:

Five-year awards provide \$2.5 million to unite population-level and laboratory-based biological sciences. The award supports the training of researchers working between existing research concentrations in population approaches to health and in basic biological sciences. The goal is to establish interdisciplinary training programs by partnering researchers working in disparate environments and intellectual frameworks.

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Innovation in Regulatory Science Awards:

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Promoting Innovation in Science and

Mathematics: Awards provide teachers with funding for materials, equipment, and training to conduct hands-on, inquiry-based science and mathematics projects in North Carolina public schools.



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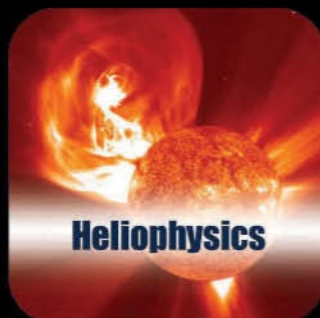
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Food for thought

From Jeff Hecht

Your investigation into whether alcohol-laced foods can make you drunk was very interesting, and carries a rather sobering warning that goes beyond driving while tipsy (20/27 December 2014, p 73).

A number of drugs don't interact well with alcohol. My wife's epilepsy medication, her doctor warns, is essentially destroyed by alcohol (presumably the alcohol somehow either inactivates it or causes the body to metabolise it faster). She is careful not to drink anything alcoholic, but we have not been watching out for alcohol in foods because we assumed that it is "burned off" during cooking.

Your story could explain an otherwise puzzling seizure she had after dining at an Italian restaurant that cooked with wine. *Auburndale, Massachusetts, US*



possible conclusions: either that human consciousness arises from calculations, or that our consciousness does not exist and is an illusion. Neither conclusion creates any barrier to sufficiently advanced machines being able to reproduce the human state of consciousness.

To come to any other conclusion, we would have to suppose that our consciousness is not entirely the product of the activity of the body, and that at least in part, consciousness exists independently of the workings of the entity that exhibits it. *Narberth, Pembrokeshire, UK*

Our calculating mind

From Ian Beaver

Mark Bishop proposes that computers will never replicate human consciousness because they are mere calculating machines (newscientist.com/article/dn26716).

But if we start from the axiom that humans are themselves calculating machines – albeit phenomenally complex ones – his reasoning permits only two

Babies versus beasts

From Christine Kowal Post

In an otherwise excellent article by Adam Roberts on animal rights (20/27 December 2014, p 78), he brings up the old chestnut that there cannot be rights without responsibilities, and would therefore deny animals rights.

Would he similarly deny babies any rights by this logic?

Lewes, East Sussex, UK

The author replies:

It's an interesting question. The thing about babies is that they eventually become grown-ups (except in those few and genuinely tragic circumstances we all hope to avoid); animals, on the other hand, are animals their whole life long. If a world existed in which babies never grew up, I suppose we might wonder whether they would have the same expectation of absolute human rights.

I have two young kids of my own. Does the fact that I and my wife cared for them when they were too young to look after themselves mean that they have a duty to look out for us when we become old and incapable? I'd like to think so. They might disagree, I suppose.

Elf lore pondered

From Ed Prior

In your article about Stephen Fry's team of "elves", who dig out facts for the *QI* quiz show, James Harkin mentions that he "read in *New Scientist* that the corona of the sun is hotter than the centre" (20/27 December 2014, p 40).

I'm not sure which article he was referring to, but the temperature of the sun's core is about 15 million °C, whereas the

corona – the outer atmospheric layer – is at around 5 million °C. It is true, however, that the corona is much hotter than the surface of the sun, which is only in the thousands of degrees. I believe that is what Harkin meant.

Why the sun's atmosphere is so much hotter than the surface is still a mystery.

Poquoson, Virginia, US

From Alan Coady

QI elf Andrew Hunter Murray's assertion that elephants can differentiate between different



human languages reminds me of the power of prosody, the patterns of stress and intonation in language.

I often hear visitors to Edinburgh chatting in supermarkets. Even when they are too far for the words to be clear, the "tunes" of speech are often enough to give away that they are new arrivals. Could this be akin to what elephants do?

Edinburgh, UK

Christmas Crossword Solution

Answers to crossword competition (20/27 December issue, page 76)

ACROSS 1. A-list 6. ATMs 10. Mass 14. Peale 15. Phon 16. Auto 17. Acmes 18. Euro 19. Gram 20. Same-sex marriage 23. Trepid 24. Byte 25. See to 27. Sabras 32. Info 35. Mini 37. Crock 38. Half-baked theory 41. Anear 42. Isla 43. A key 44. Does in 46. Needs 48. Toto 50. Battle 54.

Plants vs Zombies 59. Rate 60. Asea 61. Molts 62. Avow 63. Leas 64. India 65. Yams 66. Et tu 67. Teeny

DOWN 1. A past 2. Le Car 3. I am me 4. Sleep sofas 5. Tessie 6. Apex 7. Thumb one's nose at 8. Moray 9. Snorts 10. Magi 11. Aura 12. Stag 13. Some 21. Edema 22. Reach 26. Tiki 28. Breastbone 29. Rook 30. Acre 31. Skyy 32. I had 33. Nano 34.

Flee 36. Idle 39. Britt 40. Taebo 45. No sale 47. Dammit 49. TV set 51. Tilde 52. Let in 53. Essay 54. Pray 55. Lava 56. Atom 57. News 58. ZaSu

Congratulations to the many readers who sent in correct or very nearly fully correct answers. The winner of a set of *New Scientist* books is Josie Nabialek of Cefn Fforest, UK.

Get a load of this

From Terry Quinn

Readers of your brief report on the watt balance made from Lego (20/27 December 2014, p 14) might be interested to see the video of the original Lego balance I made last year with my then 11-year-old grandson Lucas and a colleague, Richard Davis (bit.ly/LegoKilo).

We showed it at the Royal Society Summer Science exhibition in London in 2013

and published an account in *Physics Education* ([doi.org/x24](https://doi.org/10.1088/0031-9120/124)). Lucas constructed the Lego part on his dining room table, I made the rest in my basement and Richard honed the intellectual firepower of the three of us.

Our version inspired the much-improved Lego balance that you describe, built by the US National Institute of Standards and Technology.
Sèvres, France

Beaver non-believer

From Glenn Mainland
Rowan Hooper's article on beavers making a comeback in Europe extols their contribution to carbon sequestration (6 December 2014, p 27).

As a Canadian farmer with a beaver-inhabited creek on my land, I have a less appreciative view of the animals.

Beavers make a valuable contribution to water conservation where their dams enable extensive wetlands to exist, particularly in wilderness areas. But when they build their dams across flowing streams, they block migrating fish, which has a negative impact on fisheries.

On my creek their dams raise upstream water levels, drowning protective riparian vegetation. In spring, the break-up of ice in the creek creates gaps in the dams, the water level drops, and we are left with easily eroded mud banks.

We Canadians owe a lot to the beaver, since the pursuit of beaver pelts was a prime mover in the opening up of the country. It would just be nice to keep them away from our streams. I fear that applies to many European waterways, too.
Red Deer County, Alberta, Canada

Schrödinger's goat

From Darren Smith
Your article about probability which featured the Monty Hall

problem – in which you have to pick a door from a choice of three in the hope of winning a car, and are then offered the chance to switch after one of the remaining two is opened to reveal to a goat – prompted me think about quantum superposition (13 December 2014, p 38).

With three doors, the odds of picking the one with the car are 1 in 3. When Monty Hall opens another door to reveal one of the two goats, switching from your original choice of door increases the odds of getting the car to 2 in 3, even though all other factors remain unchanged.

I can't help thinking that there's a link to quantum mechanics, in that an indirect measurement (in this case, opening another door to reveal a goat) can alter the probability of a particular outcome, one that you would assume is predetermined.
Horsham, West Sussex, UK

From Mark Pettigrew
Your excellent article on probability got me thinking anew about the famously vexing Monty Hall problem. I came up with the following reformulation which I hope makes the solution easier to understand for those who still have doubts.

Once you've chosen a door, you can either keep it or you can give it up and have both the other two doors. If you opt for the latter, the host will open one of the two, always revealing a goat. Now it's your turn, and if the one you open contains the car, you win.

In this scenario, it feels easier to understand that I should opt to foresake my original door.
Sheffield, UK

From Leslie Coull
The Monty Hall problem has a more elegant solution than the one described in your article.

If I don't switch doors I have a 1 in 3 chance of winning. However, if I do switch I have a 1 in 3 chance of losing.
Nyon, Switzerland

It can't be just us

From Tan Kucuk
I was surprised to read Helen Thomson's article on the first person to report persistent déjà vu stemming from anxiety rather



than a neurological disorder (20/27 December 2014, p 8).

I myself frequently experienced déjà vu during my high-school years. I didn't have a neurological disorder, but was rather anxious and stressed at the time.

I do not believe déjà vu to be a common symptom of stress, but I had thought that people with this combination would have been reported long ago. Perhaps my case was mild; I did, however, often become stressed and then have déjà vu for several days, either in a row or every other day.

Maybe there are far more unreported cases of this kind?
Kyleakin, Isle of Skye, UK

Helpful robots

From Patricia Browne
In your 2015 preview, Hal Hodson writes about humanoid rescue robots (20/27 December 2014, p 26).

I would suggest giving them four arms and four hands. Such a robot could push down a wall with one pair of arms and clear the rubble with the other set, likely progressing more quickly. Or it could climb or descend slopes to make a rescue with more dexterity along the way.

This would also make them more useful for everyday tasks.

When raising my small children I often wished for more arms and hands. Just try pushing a stroller while carrying a few parcels, holding a toddler's hand and negotiating a street crossing or car park.

A four-armed robot could open doors or gates while carrying parcels, and could be especially useful in helping immobile people. So can someone redesign the helpful robot to be even more handy?
Caringbah, New South Wales, Australia

Worm eaten

From Tim Stevenson
So you endorse the view that the early bird catches the worm (20/27 December 2014, p 71). Last readers draw an inappropriate moral from this, let me point out the corollary that the early worm is caught by the bird.
Prestwood, Buckinghamshire, UK

From Ralph Reid
Regarding the myth that you can't teach an old dog new tricks, the answer is simple – to a sufficiently old dog, there are no new tricks.
Coolamon, New South Wales, Australia

For the record

■ A small error appeared in our article on animal rights (20/27 December 2014, p 78): smallpox is a virus, not a bacterium.

■ Bad seed: we misnamed the Global Crop Diversity Trust in our interview with Cary Fowler (3 January, p 23)

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FEEDBACK was not aware that any other language had a synonym for the Yiddish *tchotchke*, “a trinket of no discernible function” (13 December 2014). So we are pleasantly surprised by the number of suggestions.

Before the ink was dry a colleague observed that “only the other day I found myself uttering the sentence ‘Little girls’ party bags just get filled with pink plastic tat.’” But we first heard “tat” in an entirely different context, referring to rather unofficial street parties: “if the cops seize our tat, we’re stuffed – can we sort backup?” To the utterers, items of “tat” were essential. A discussion on attitudes to needs and possessions, and the effects of parenthood on these, ensued.

OTHER nominations for *tchotchke* synonyms included John Rawson’s “mathom”, defined as “the hobbit term for anything which they had no use for but were unwilling to throw away”.

The hobbits’ creator John Ronald Reuel Tolkien was a language scholar. We cannot rule out his engaging in a quest parallel to ours, only to cheat by attempting his own synonym.

Andrew Shead and Iain Wallace mentioned *geegaw*, which Iain identifies as Scots. Never having lived in Scotland proper (we think Edinburgh hardly counts for these purposes), Feedback cannot be sure, but we believe *geegaws* are necessarily shiny: a *tchotchke* can be as dull as you like.

Judith Woolf, also a language-related scholar, supplies another Scots delight: a *whigmaleerie* is “a fancy ornament or small and useless knick-knack”. We agree that the word “comes in handy for Feedback in its alternative sense: a fanciful notion or contrivance”.

SHOULD your home be infested by *whigmaleeries*, you may be thinking about recycling. We witnessed the

distress of a German-speaking neighbour deprived of the chance to lovingly sort unwanted things when her council switched to a single recycling bin (29 March 2014). She may have been more at home in the Netherlands where in 1989, Patrick Fenlon reports, householders had to sort out 10 different categories from “machinery” via “rubble” to “other”.

Funnily enough, we have since found a small spate of alarm about this. “Families may have to separate rubbish into six separate bins due to European regulations coming into force in January” complained *The Daily Telegraph* in August 2014. In October 2013 the threat had been smaller: “At least FOUR recycling boxes for EVERY home” was the fear of the *Daily Mail*. But that story carries a correction online: “local authorities can comply without requiring households to use separate bins”. A storm in a chipped teacup, then. (But would a ceramic teacup be “rubble” or “other”?)

SEVERAL readers congratulated us on the recursive nature of the column which opened “Muphry’s Law holds... that whenever one criticises editing or proofreading, there will be a fault in what you have written.” (6 December 2014). We should perhaps have repeated that the law was named in 1992 by John Bangsund of the Victorian Society of Editors – the Australian state, not the reign – in a self-referential homage to Murphy of “if it can go wrong, it will” fame (1 March 2014). Extensive research into the matter reveals that it has also been named the “Law of Pedantic Reverberation”. Where? Er, here (2 October 1999).

WHATEVER we call the above-mentioned law mandating an error for an error, it has once more been tested, and again not falsified. John Cockton queried our explanation for marking *New Scientist*’s numerical millennium with issue 3002, because issue 3001 had been absorbed into a seasonal double issue (3 January). Should we have adjusted for previous such issues? As we were replying ruefully to John that whatever arithmetic we

did would likely be plagued by what computer programmers call an “off-by-one error”, another message arrived from Chris Ford: “Er, isn’t your edition 3002 the dawn of your *fourth* millennium?”. Whoops.

TEMPTING Muphry once more, we return to safety precautions at the Francis Crick Institute, a medical research facility being build next to St Pancras station in London (20/27 December 2014). Biological hazards are graded on a whole-number scale.

The Institute assures us that it will not handle level 4 bugs but also that its hazard rating is greater than 3. Colin del Strother concludes that, whatever the safety issues, “the discovery of a new integer between 3 and 4 must be of some scientific interest.”



FINALLY, there must be a parallel law governing metaphorical quantitative help for readers. Feedback mentioned another publication’s observation that plucky little lander Philae had the same weight as a newborn elephant (6 December 2014). Meanwhile on page 46 of that issue, as four readers pointed out, pressure at the bottom of Challenger Deep in the Mariana Trench “is equivalent to having two elephants standing on your big toe”. Was this deliberate, we asked a colleague. “Absolutely. Metric elephants, *naturellement*.”

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A website asked John Gibson “What is your lucky number?” as a security question. It then complained his answer was too short. “If I pick a longer one, it won’t be my lucky number...”

Odd jobs

This picture (right) shows some strange objects I have recently seen in three places near my home - twice on verges of country roads and once near a stable's muck heap. They are small spheres, between 2 and 4 centimetres in diameter, and very hard. They are nearly black inside, with terracotta-coloured skin. Each site had several hundred of the objects in a rough heap about a metre across. Have they been manufactured for a purpose? If so, why are they being dumped? Or are they natural? If so, what created them?

■ These are expanded clay pellets or aggregate. They are produced by firing natural clay at high temperatures in a rotating kiln to produce spherical pellets with a terracotta-like surface. A black porous core is formed by burning organic materials within.

Aggregate is manufactured for many purposes, including for use in building materials such as blocks, slabs and concrete. It is useful for this because the clay pellets are lightweight and are excellent insulators of sound and heat, and they are resistant to rot and chemical degradation.

It is also often used in building situations where loads need to be minimised, such as in the substrate above a tunnel where the pellets also provide stability



and efficient drainage. Additionally, the pellets can be used for water treatment due to their high surface area, which aids the absorption of pollutants.

The ones shown have most likely been used as a growing medium and discarded. The clay allows for the absorption and retention of water as well as allowing the drainage of excess water from around the roots of whatever is planted in them. This ensures that air circulates throughout the medium and the porous pellets, maximising oxygen uptake.

They are often used with a constant or regular water supply such as a drip feed or an ebb and flow system. The pellets can maintain a neutral pH as well as providing a large cation-exchange capacity for the retention and provision of plant nutrients added to the water.

Because they have been left in relatively small heaps by the road, it's not unreasonable to

suggest that they have been used as a growing medium for the cultivation of cannabis, dumped within a rural environment to avoid suspicion.

*Patrick Melia
Brighton, UK*

Waxwork horrors

I left a tea light candle on my windowsill for six months in a transparent plastic box. It now looks very strange (see photo, right). How did this happen to the wax?

■ I believe this pattern has formed due to the crystallisation of paraffin molecules, perhaps caused by daily warming on the window ledge.

Paraffin has a tendency to dissolve as the temperature rises, followed by a tendency to crystallise as the temperature falls. This is called thermally cycled recrystallisation, and is common in industry with sugar,

salts and so forth. It is also used to form crystals out of biological proteins, to allow for X-ray diffraction analysis of a protein's molecular structure.

A clue to this crystallisation is the lack of colour in the growths. Because the pigment is a different molecular shape and size to the paraffin molecules, the paraffin molecules displace the dye as the crystals grow and shrink. A close examination might show a coloured halo around the crystals where the expelled dye is a little more concentrated. Eventually the paraffin molecules will join together to become a mass of pure paraffin.

*Bill Jackson
Toronto, Ontario, Canada*



"The pellets are produced by firing natural clay at high temperatures and are very resistant to rot"

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This week's question

CIRCUIT JUDGE

During a blackout, does electricity reverse its flow from the battery of my phone to the charger or power outlet?

*Roque Mansiliohan
San Luis, the Philippines*

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Dr Louise Wong,
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